NOKIA CONTRIBUTION

To the Second Consultation Paper Issued by the Info-Communications Media Development Authority of Singapore on

5G Mobile Services and Networks

FOR THE ATTENTION OF:

Ms Aileen Chia
Director General (Telecoms and Post)
Deputy CE (policy & Competition Development)
Infocomm Media Development Authority of Singapore
10 Pasir Panjang Road
#03-01 Mapletree Business City
Singapore 117438

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Author	Guillaume Mascot
	Head of Government Relations APJ
	Nokia
	guillaume.mascot@nokia.com

NOKIA

Contents

1 About Nokia

We create the technology to connect the world. We develop and deliver the industry's only end-to-end portfolio of network equipment, software, services and licensing that is available globally. Our customers include communications service providers whose combined networks support 6.1 billion subscriptions, as well as enterprises in the private and public sector that use our network portfolio to increase productivity and enrich lives.

With an end-to-end portfolio that is unique in the industry, Nokia can work in partnership with operators to deliver "real 5G". Nokia's in house 5G mmWave Small Cells and AirScale BTS provide in-building and outdoor coverage, while our Microwave Anyhaul, Cloud native RAN, antennas, and 5G cloud-native core are part of approximately half of our agreements to date. Beyond our mobile networks portfolio, Nokia has excellent FP4 network processor-based IP routers and PSE- 3 chipset powered optical networking - our customers can use the Nokia Network Services Platform to make this into full-5G-strength software defined connectivity 'smart network fabric' secured by Nokia Security Orchestration, Analytics and Response (Nokia SOAR) to ensure resilient 5G.

As of June 2019, Nokia confirms its 5G leadership position with 42 commercial 5G deals in place with operators around the world, 22 with named customers such as T-Mobile, Telia Company and Softbank. Including these agreements, Nokia's 5G deals, trials and demos total over 100 5G customer engagements to date.

Through our research teams, including the world-renowned Nokia Bell Labs, we are leading the world to adopt end-to-end 5G networks that are faster, more secure and capable of revolutionizing lives, economies and societies. Nokia adheres to the highest ethical business standards as we create technology with social purpose, quality and integrity.

For more information: https://www.nokia.com/networks/5g/

Disclaimer: This response is based on Nokia's current understanding of the market dynamics and various standards bodies; these dynamics are changing and hence our views may update with these changes

2 Singapore future – 5G potential use cases and skill requirements

Question 1: IMDA would like to seek the industry's views on skills requirements and the potential job demands in the future of networks and next generation of application/use-cases with 5G technology.

Driving 5G into the future would require an amalgamation of skillsets when we are comparing with the capabilities that we have in the industry today. Here are some high-level view on the skillsets required:

- 5G is driven to transform the digital transformation of industries and this would require capabilities that extend beyond just the knowledge of 5G into the overall business process and the overall solutions integrating the end use cases, the 5G network and the applications/analytics to form the overall approach in the digital transformation of these industries
- With Cloud and Analytics playing a key role in the building blocks of 5G, there would need to be a growth in this crucial area to ensure we are able to unlock the capabilities of 5G.
- With 5G powering IoTs, critical would be the discussions around privacy, security and safety. This would be not only around technical capabilities but also enhancement of regulatory framework to establish the required guidelines around this.

Question 2: IMDA would like to seek views on:
i) The types of innovative use-cases that could capitalise and further enhance Singapore's competitive advantages, trigger new growth potential and/or strengthen Singapore's existing strategic pillars; and
ii) Areas of government support that the industry require in order to enable innovation and development in 5G.

5G is going to change everything, every industry, every business, and every consumer experience. It will power massive broadband applications and it will create unprecedented opportunities. Nokia is leading 5G innovation. We have announced 5G commercial contracts with 42 customers and we have over 100 engagements in total with our customers. As an example, Nokia's 5G project in the Port of Hamburg received the GLOMO (GSMA Global Mobile) award at MWC2019. This Port became a testing ground for 5G applications in an industrial environment.

Here are some business cases, Nokia considers for Singapore:

Smart Factories: As Singapore realizes its Smart Nation initiatives, more businesses are seeking to boost the productivity and flexibility of their production or provision of services while securing a safer workplace. They want to deliver more personalised offerings to better meet fast-changing consumer demands, which requires higher degrees of automation. For manufacturing-based industries, 5G can facilitate more machine-type communications (MTC), real-time control of machines, robot-human interactions and edge cloud analytics to create "smart factories".

Ports: Another key area of industry will be around the harbor, which is particularly important with the Port of Singapore's status as the world's leading bunkering port. 5G can help foster the creation of "connected ports", one where humans can interact with and share real-time information with devices and machines. For instance, with lower latency, loading and unloading operations can be made more efficient via the automated remote control of unmanned ground vehicles. Not only can this help streamline operations at ports to reduce harboring times, it can reduce the risk of human injuries and fatalities when carrying out such operations.

SMEs: Meanwhile, SMEs can benefit from 5G coupled with Machine Learning and Artificial Intelligence improving the efficiency of back-end operations by leveraging more sophisticated cloud computing for network-related tasks. On the front-end, 5G will help staff better respond to customer queries, namely via communicating with workers through remote access software more efficiently. The 5G speed will be crucial for these small businesses to operate with higher productivity and survive and thrive in Singapore's highly-competitive business environment.

Consumers: One of the most obvious consumer benefits from 5G will be much faster broadband speeds for content consumption. With the rise of online streaming services, more people are turning parts of their homes into home entertainment systems, especially since more 4K (and soon 8K) content will be made readily available by streaming services. 5G will help to ensure that the viewing experience will be smooth and lag-free.

Additionally, 5G developments have coincided with the rise of virtual reality technology. As such, 5G will make it more realistic for people to virtually participate in a live music or sports event, as the ultra-fast broadband speeds can better ensure that the consumer stays connected and engaged with the event.

Gaming is another space 5G connectivity will transform. Singapore alone has more than 1.4 million gamers, with an estimated total market value of over US$100 million. This market is set to grow as competition heats up within the competitive esports sector. This is where lower latency is vital to a competitor's performance, and to the fans who follow the gamers during live online streams. Outside of competitions, 5G can also raise the at-home experience of casual gamers, especially as industry leaders such as PlayStation are going the subscription-based route of Spotify and Netflix. Until now, however, not everyone has been convinced that cloud gaming would raise the experience due to latency and lag concerns - both of which 5G is well able to address.

In November last year, Nokia completed the city-state's first outdoor pilot of 5G New Radio (NR) on the 3.5GHz frequency band in Singapore. We did this essentially to test its application for businesses and consumers.

On one hand, we managed to demonstrate its use for a sector that has been typically hard to digitalize: manufacturing. Specifically, it was to show how businesses can use 5G-enabled video analytics to improve efficiency and cut down on production errors. These efficiencies can be applied to many forms of industrial facilities such as factories and power plants. This may, to some degree, help circumvent the limitations of Singapore's geography, especially when it comes to industrial space.

The other use case demonstrated was, arguably, a bit more novel: how sports fans can use 5G-enabled VR headsets to have immersive video experience at a live sports event, making them feel like they are there in person.

3 C-Band and Guard Band

Question 3: IMDA would like to seek views and comments on the suitable technical parameters, including the reasonable amount of guard band needed to reduce potential interference between IMT and FSS use in the 3.5 GHz band.

Nokia's recommendation is that IMDA review the purpose of having a large portion of unused spectrum between 3.6GHz and 3.7GHz to be devoted as a guard band.

Nokia has developed several independent studies[1][2][3] and filed these studies to the FCC when the US regulators started the proceeding of the C-band. The C-Band Alliance (FSS providers such as Intelsat/SES) has supported these studies[4].

Our study concludes that co-channel deployment of 5G and FSS Earth Stations (ESs) could incur significant interference to FSS ESs when in close proximity to each other. Since co-channel operation of 5G and FSS fixed earth stations in close proximity could be problematic, we studied the case where the two systems are not using the same spectrum blocks using the following stringent spectrum mask for 5G Base Stations to protect FES ESs.

- -3dBm/1MHz from 0 to 20MHz offset from the 5G spectrum block
- -40dBm/1MHz from 20MHz to 40MHz offset from the 5G spectrum block
- -50dBm/1MHz for frequency offset greater than 40MHz

Based on these coexistence considerations, Nokia recommended to the FCC to clear the band of FSS ESs, especially when in close proximity of 5G systems to allow 5G systems to thrive in the band and avoid co-channel deployments of FSS and 5G.

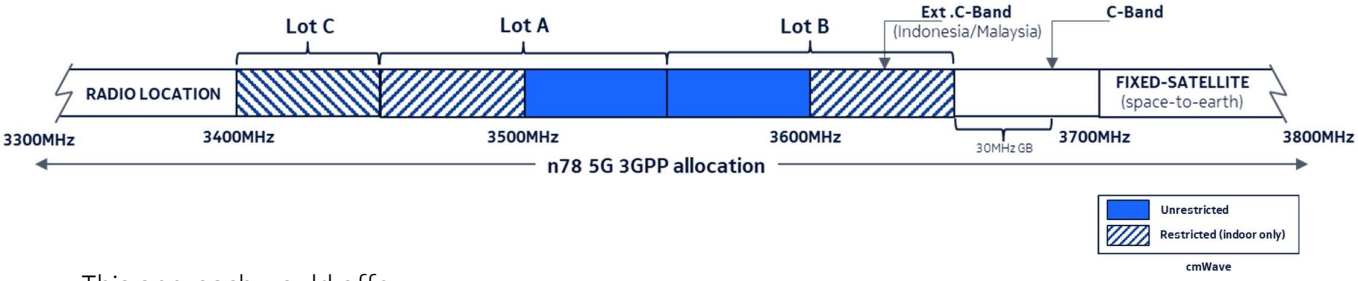
Nokia also believes that the 20 MHz guard band would be enough for a filter on the earth station receiver to provide the necessary rejection performance that would prevent 5G transmission from saturating the Low Noise Block converter (LNB) of the earth stations if that proves to be an issue. Such an external filter should be tunable across 3700-4200 MHz band. We do not foresee that this would translate into additional requirements on the 5G system. The FSS providers can work with manufacturers to define the filter characteristics such as rejection, roll-off, and insertion loss.

[1] https://ecfsapi.fcc.gov/file/102976959340/Nokia%20Comments%20on%203.7%2010-29-2018%20FINAL.pdf
[2] https://ecfsapi.fcc.gov/file/1203063247152/3%20GHz%20%20Correction%20Letter%20FINAL.pdf
[3] https://ecfsapi.fcc.gov/file/12112324518278/Nokia%203%20GHz%20Reply%20Comments%20FINAL.pdf
[4] http://www.intelsat.com/wp-content/uploads/2018/12/C-band-Reply-Technical-Annex-for-Reply-Comments-of-the-C-Band-Alliance-20181207.pdf

We understand that satellite services are potentially operating as low as 3.68GHz in the C-band range, and that neighboring countries such as Indonesia and Malaysia might still have services operating in the extended C band range as low as 3.625GHz for FSS.

An alternative proposal is to use 50MHz of the originally proposed 100 MHz guard band for indoor purpose only, more specifically mirror the proposal of option Lot A that is currently allocated at 3.45GHz ~ 3.55GHz (with 100MHz BW of which the first 50MHz are for indoor use only, and the other 50MHz unrestricted). Meaning Lot B would operate at 3.55GHz and 3.65GHz (100MHz BW) with the first 50MHz unrestricted and the new upper 50MHz be only used for indoor purposes. This creates an equal playing field of 100 MHz for 2 lots of spectrum.

Therefore, Nokia would like to propose this new allocation:



This approach would offer:

- An extra 50MHz (3.6GHz~3.65GHz) for indoor use only
- A natural 80 MHz guard band with outdoor macro systems and a 30MHz guard band indoor guard band to C-band service
- Implications of collocated spectrum (extended C-band) in neighboring countries as the spectrum in Singapore would be for indoor deployments using low power solutions and will be separated by a minimum of 1 km range to neighboring countries

As indicated in the APSCC, CASBAA, ESOA and GVF answer to the first consultation[5], the indoor use could be considered:

"ITU and APT studies have shown that the separation distances required to offer adequate protection to FSS receivers in respect of out-of-band emissions of 5G transmitters, assuming no guard band between the satellite and 5G signals are in the range of: less than a kilometer for 5G microcell outdoor deployment, and tens of kilometers for 5G microcell outdoor deployment. In addition to limiting mobile deployments in the 3.6-4.2 band to small cells, IMDA may want to consider further limiting such deployment to indoor use only…"

This proposed conservative approach has the mere objective to offer equal lots based on the initial proposal of IMDA. But as indicated, we strongly believe that a smaller guard band is achievable. On

[5] See page 8 - https://www2.imda.gov.sg/-/media/Imda/Files/Inner/PCDG/Consultations/consultation-paper/Public-Consultation-on-5G-Mobile-Services-and-Networks/2017-07-06-DRAFT-Satellite-Comments-on-IMDA-5G-Consultation.pdf

a similar approach, IMDA could even go further and allocate 3.6GHz~3.65GHz as unrestricted and 3.65GHz~3.68GHz as indoor providing as such 30 MHz guard band.

4 Identifications of other 5G Bands

Question 4: IMDA would like to seek views and comments on the following:

i) Whether the industry agrees with the timelines on the expected availability of the next wave of 5G spectrum; and

Regarding the expected availability of the next wave of 5G spectrum, Nokia considers that IMDA should already start the feasibility study and potential migration of existing services especially for sub-700 MHz and 4.5 GHz.

The 600 MHz band is rising in importance in countries in the Americas and in some countries in Asia-Pacific for IoT use in remote areas and for indoor penetration in urban areas. In the United States, following the Voluntary Incentive Auction of the 600 MHz band, T-Mobile and Nokia have completed the world's first 5G data transmission over "low-band" 600MHz radio spectrum in November 2018. T-Mobile is looking for a broad and potentially fast rollout of 5G services across the United States on this band.

The 4.5GHz has been allocated in Japan in April 2019 and China is also considering this band for future deployment. As indicated in the IMDA paper, the migration can be challenging, therefore we encourage IMDA to start potential use for 5G.

Finally, we support IMDA in its effort to make 700 MHz available in Singapore. We understand the challenge related to neighbouring countries and hope that a full use of this band will soon be possible as it is considered as a major band for 5G.

On 2.1 GHz, Nokia welcomes IMDA decision for further consultation.

ii) Whether current deployments in the 2.5 GHz FDD spectrum band (based on 3GPP Band 7) and in the 2.5 GHz TDD spectrum band (based on 3GPP Band 38), should be refarmed to 3GPP Band 41 for future 5G services in Singapore, and the views on the associated cost and challenges.

The 2.5GHz spectrum band (based on 3GPP Band 7) is currently heavily used by operators and any refarming exercise will create uncertainty. While Nokia acknowledges that Band 41 is an excellent choice for 5G, Nokia does not recommend to refarm this band at this stage. IMDA should engage with operators on potential future use of this band for 5G.

5 Proposed spectrum allocation

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;

Nokia's view is that IMDA timeline for mmWave is justified, and Nokia fully supports it. Nevertheless, the timeline for the cmWave band 3.5GHz should be accelerated with an objective of availability early 2020.

On the subject of the IMDA recommendation of SA only, Nokia would like to highlight that it is unusual for a regulator to drive a particular network architecture. The more usual approach, and the one that Nokia sees occurring globally, is for this type of decision to be driven by operators. Adoption of a particular architecture will be based on an operator's commercial concerns, their technical capabilities and the available ecosystems. In this regard, Nokia would recommend following a similar model in Singapore. In this way, the ability of Singaporean operators to provide innovative 5G solutions to Singaporean citizens will not be unnecessarily constrained.

On a technical level, Nokia notes that SA architecture is already available with 3GPP Release 15 i.e. therefore there is no need to couple SA with 3GPP release 16. Furthermore, 3GPP will not finalize 3GPP release 16 standards until the end of 2020. 3GPP Rel-16 compliant networks and UEs will therefore only be available during 2021 at the earliest.

With regard to SA with mm wave, Nokia notes that this is straightforward from the perspective of (Nokia's) network implementation. However, according to our understanding, not sufficient chipset vendors are as yet supporting or planning to support this combination to create a viable eco-system in the short term.

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

As mentioned in question 3 response, IMDA should consider opening more spectrum that could allow for potential up to 3 lots of spectrum for an optimal use of this resource. Nokia believes that a minimum of 250MHz of spectrum can be released for use in Singapore. This is important since maximising the amount of spectrum that is released and utilised will benefit and foster competition, innovation and consumer experience.

Current IMDA proposal is not optimal with 50MHz left unsold and a conservative guard band (GB) of 100 MHz. Nokia considers that 20MHz guard band is sufficient or at least an additional 50MHz can be allocated on the upper part. We therefore suggest to:

1. Propose total of 3 Lots of spectrum blocks
    a) Lot A – 3.45~3.55GHz (50MHz indoor & 50MHz indoor/outdoor) as per IMDA original recommendation
    b) Lot B – 3.55~3.65GHz (50MHz indoor & 50MHz indoor/outdoor)
    c) Lot C – 3.4~3.45GHz (50MHz indoor only) new policy considerations see response in point iv)
2. Mirror Lot A to Lot B – using 50MHz of original guard band (new concept)
3. Mitigation of 50MHz within guard band (100MHz from 3.6~3.7GHz)
    a) Lot B finish at 3.65GHz (indoor component) still offers 80MHz of guard band to outdoor systems, and 30MHz guard band with indoor systems for C-Band users

within Singapore. Considering that the indoor systems are radiating >20dB less than outdoor systems, plus have an indoor-to-outdoor path loss to contend with we believe we are still being conservative with the approach proposed.

b) Since Lot B 3.6~3.65GHz is for indoor use only (low power), and deployed 1km from Indonesia/Malaysia offers natural guard band.

4. Operator can use Lot B, and will have to manage any interference between C-Band and 5G services
5. When neighbouring countries remove ext.C-band use, then full unrestricted 100MHz use of Lot A and B possible estimated 2022/23, and this is still offering a 30MHz guard band to C-band operation, which could also be studied for restricted use.

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

Yes, there are solutions within Nokia portfolio that can support multiple of 50MHz blocks in the cmWave, but the majority of vendor equipment currently support only multiple of 20MHz up to 100 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;

Nokia is proposing to develop a Lot C that would be restricted to indoor use only. As this lot will have some restriction, Lot C could have a first right related to mmWave preferred portion allocation (response in point v).

Lot C could never meet the throughput KPIs of Lot A or B, also would not be able to achieve 50% island coverage, due to its bandwidth restriction, and indoor use only.

Other KPIs could be imposed since most operators claim >70% of traffic generated/terminated happens indoors[6].

As such only outdoor coverage should be stipulated, but also specific buildings where coverage should also be provided e.g. Shopping centres, Stadium, hospitals, and all intersecting and major junction MRT lines i.e. Newton Circus, Dhoby Ghaut. Stations like Orchard, Somerset would be optional as they don't fall under interchanging lines. Other mandatory locations would be universities, the national gallery, and library as part of the indoor KPI requirement.

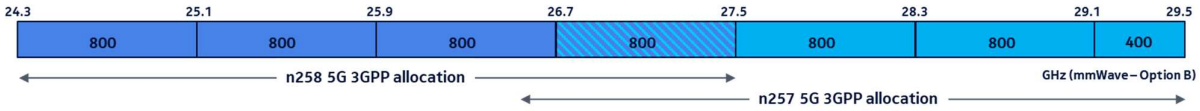
Therefore, rather than focusing on island coverage, IMDA should rather promote population coverage. This would benefit Singaporeans and the Return of Investment of operators within the initial 2-year period. Subsequent targets could focus on island wide coverage for Singapore, when low band 5G services could be implemented providing a more economical solution for operators to achieve a national coverage.

[6] https://www.abiresearch.com/press/abi-research-anticipates-building-mobile-data-traf/
http://blog.tmcnet.com/next-generation-communications/2014/10/most-mobile-traffic-happens-in-building-and-operators-need-to-beef-up-their-support.html
https://blog.mobile-network-testing.com/capacity-enhancements/hetnets-small-cells-indoor-deployments/

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

Nokia agrees that the portion of mmWave allocated is generous. With a preference for Option B. Since Lot C (cmWave) remains for indoor use only, they have the first right for mmWave 800MHz block choice

a) Lot C will most likely choose 26.7~27.5GHz to benefit n257/n258 devices
b) Lot A & B will be allowed to choose an 800MHz block from n257 each
c) Lot C then can have the advance of 25.9~26.7GHz block (contiguous use 1.6GHz) guard band if necessary would be managed by Lot C
d) Lot A & B will be allowed to choose an 800MHz block from n258 remaining each



The final lot 29.1~29.5GHz could be permitted for special indoor Industry allocation only – restricted to industry zone (Class License shared)

This 400MHz could be applied by CSP, or Enterprise to deliver an indoor restricted to Enterprise service, that is operating within the perimeter of the campus, or industrial site building.

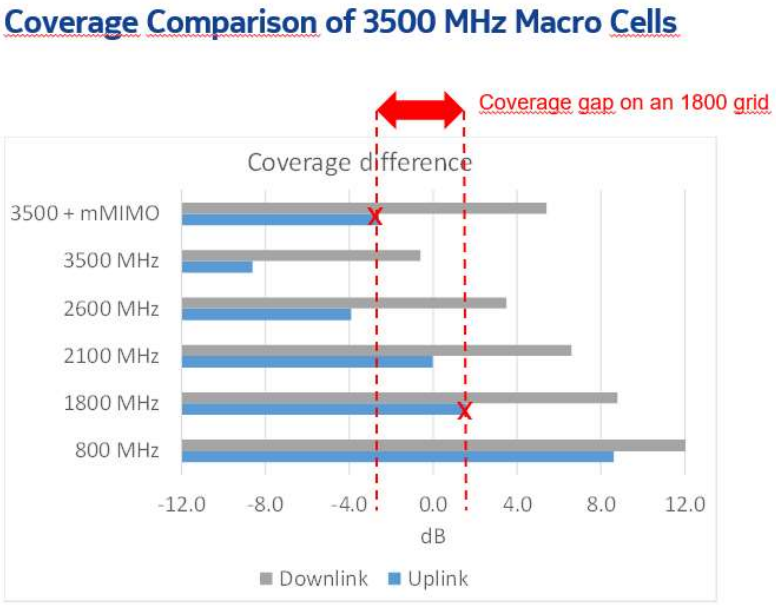
vi) The rank order preference of the 3.5 GHz spectrum package and mmWave lot combinations.

1. Option B (preference)
2. Option A
3. Option C

6 Network design

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;

Cellular coverage has been realized in GSM, WCDMA and LTE via the usage of a sub 1 GHz band in rural and e.g. a 1800 MHz band in urban areas. As can be seen the diagram below, even with the usage of mMIMO in the cm-wave (which gives a 6dB improvement compared to 2T2R), there is still a coverage gap between cm-wave and 1800 MHz This will manifest itself as a coverage gap when cm-wave is deployed on an 1800 MHz grid.



With mm-wave, whose propagation characteristics are even more limited than those of cm-wave, this gap will be even larger. Nokia therefore considers that a coverage-based performance metric for the deployment of cm and mm-wave 5G bands is not a realistic proposal. Nokia would suggest that a population-based metric would be more suitable, especially if the IMDA were to introduce a Lot C in accordance with Nokia's proposal.

For a coverage-based performance metric to be realisable in practice, a coverage augmentation mechanism would be required. This could be via usage of Dual Connectivity in Non-Standalone 3X architecture (where the 5G coverage is boosted with the usage of LTE Uplink at the cell edge) or with re-farming of an existing sub 3 GHz existing cellular band to 5G.
As noted in answers to Question 5, Nokia considers the IMDA proposed limitation to Standalone Architecture as unnecessarily restrictive and not in keeping with the desire to promote a flourishing 5G ecosystem in Singapore.

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

For coverage verification, IMDA should work on a combination of the following methods to show aggregate coverage performance of the network:

(a) Geo-located Device-level OSS statistics

(b) MDT (Minimization of Drive Test) feature measurements

(c) Vehicle drive test measurements of 5G signal and performance

When a coverage area has large number of device connections, methods (a) and (b) give reliable verification of 5G coverage provided measurements also show better performance than 3G/LTE. In areas with small number of connectivity, method (c) can be used.

Since initial 5G launch will not have the same coverage as 3G/LTE, it is recommended that operators also show handover between LTE and 5G areas to ensure seamless user-experience.

Note should the Nokia proposal for a Lot 3 be accepted, in the interests of fairness, a different metric would be required for the purchaser of that Lot. Note that a relaxation of the licence requirement for 5G to be standalone would resolve this issue – it is far easier to provide coverage with mm wave in e.g. dual connectivity mode with a lower frequency band than for SA with mm wave only.

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

To enable Sharing, Slicing, Cloud and Edge networking in a 5G network, multi-vendor interworking is ultimately required. Slicing implementation can be complicated to fulfill across consumer, enterprise and multiple industries by a single vendor especially when enterprise customers may plan to leverage (upgrade) their existing IT/Cloud infrastructure to support their respective slices. The immediate challenge is the design for an open and shared network but where a common and consistent policy of trust and resiliency can be implemented across 5G Protocol, Networking, Cloud and Information Security.

A multi-vendor multi-connectivity architecture requires accord and potential sharing/extension of responsibilities between MNOs, MVNOs, shared facilities, enterprise networks, and equipment vendors.

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

5G wholesale services allow operators to create new business models but competition in services offering is critical

As with any new technology, there are several unknowns in the evolution of 5G use-cases and the network features to support them. While wholesale agreements are expected, MNOs and MVNOs must be flexible and adapt to 5G developments in the years ahead.

7 Spectrum Assignment Framework

Question 7: IMDA would like to seek views, comments and suggestions on the spectrum assignment framework, including:

i) The proposed assignment approach;

As suggested in question 3 and 5
Nokia would like to propose a total of 3 Lots of spectrum blocks

1. Lot A – 3.45~3.55GHz (50MHz indoor & 50MHz indoor/outdoor) as per IMDA original recommendation
2. Lot B – 3.55~3.65GHz (50MHz indoor & 50MHz indoor/outdoor)
3. Lot C – 3.4~3.45GHz (50MHz indoor only) with indoor policy KPI applied

4. Lot C will most likely choose 26.7~27.5GHz to benefit n257/n258 devices
5. Lot A & B will be allowed to choose an 800MHz block from n257 each
6. Lot C then can have the advance of 25.9~26.7GHz block (contiguous use 1.6GHz)
7. Lot A & B will be allowed to choose an 800MHz block from n258 remaining each
8. The final lot 29.1~29.5GHz could be permitted for special indoor Industry allocation only

ii) The spectrum right duration of the 3.5 GHz package and mmWave lots;

The spectrum right duration proposed by IMDA (between 12-15 years) are reasonable and is giving operators the necessary timeframe and incentives to continuously invest and upgrade their networks. In addition to the duration, transparent renewal conditions would justify continuing investments at near license end-dates, avoiding investments gaps until the license renewal.

iii) The evaluation criteria, sub-criteria and weights to assess the proposals;

Nokia has no comment

iv) The assessment methodology, including evidence (documentary or otherwise) to evaluate the proposals; and

Nokia has no comment

v) The enforcement and/or audit mechanisms to ensure that applicants are able to deliver on their proposals.

Nokia has no comment

8 Infrastructure Sharing

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.

Infrastructure sharing options:

Considering the current limitation in the spectrum allocation plan, it is expected to see further sharing across operators in Singapore market would they all wish to offer 5G services to their subscribers.

Several sharing options are available across radio transport and core. Considering Singapore context, the following cases could be considered:

- **Wholesale** based on National Roaming: in this scenario the 5G network is built by one single operator and partnering operators or MVNOs without 5G licenses access the 5G resources (radio, transport and some of the core) in a given geographical area. The level of sharing elements will depend on the existing assets of the partner.

- **Multi-Operator Core network (MOCN)**: in this scenario, different operators enter into a business agreement to share one single 5G spectrum. The RAN infrastructure is shared, while it is expected that operators will retain and evolve their own core towards 5G in order to keep a certain level of service and strategy differentiations. The transport from the site to the first point of common aggregation is shared as well.

Would IMDA allocate only 2 (or 3) spectrum lots for 5G, additional sharing amongst successful entities is possible to further reduce the deployment cost, namely **MORAN (Multi-Operator RAN)**. In this scenario the RAN is actively shared amongst both entities and both spectrum are radiated from the site. Note that all sharing models could coexist (wholesale, MOCN, MORAN), as at least one entity could be a consortium amongst operators as illustrated below.

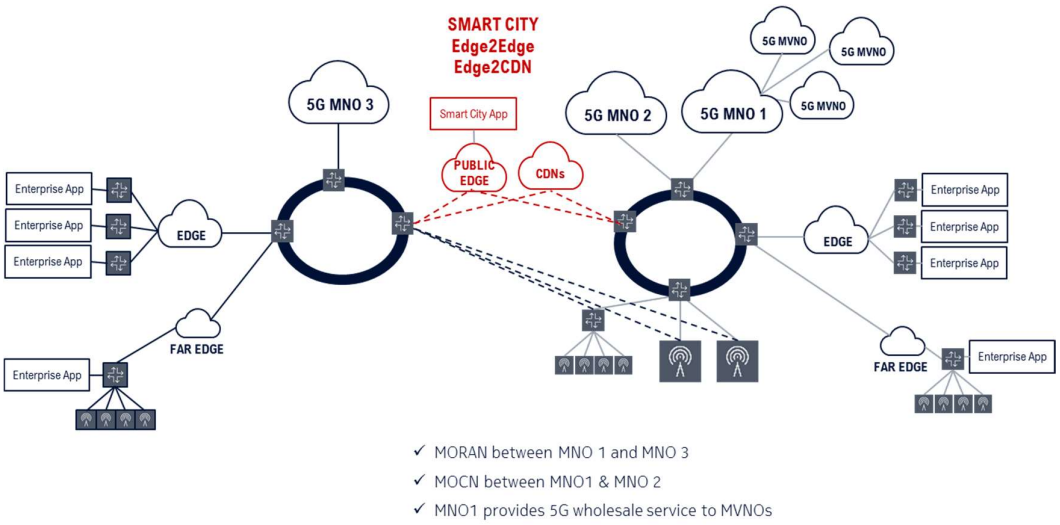


Figure 1: Possible sharing options across 5G

Trade-off on 5G capability:

- MOCN: operators sharing the same RAN will have a lower degree of freedom in terms of RAN feature as they share the same feature set at cell level. Feature differentiation is possible at site level only.

  Agreement at the consortium level with regards to criteria for RAN deployment and architecture choice (distributed, cloud, edge) would need to be clearly stated to ensure both operators remain competitive to attract enterprise subscribers

  It is expected that radio and potentially transport to the first point of aggregation only will be shared inside the consortium, leaving core and edge core under each operator control to ensure strategy and service differentiation.

- Wholesale: as per usual wholesale agreement, the operator deploying the network is the sole decision owner in terms of feature implementation. MVNOs often differentiate on service packaging and customer care.
- MORAN: full differentiation at RAN level is kept as operators will define their own feature set at cell level.

Agreement at the consortium level with regards to criteria for RAN deployment and architecture choice (distributed, cloud, edge) would need to be clearly stated to ensure both operators remain competitive to attract enterprise subscribers.

It is expected that radio and potentially transport to the first point of aggregation only will be shared inside the consortium, leaving core and edge core under each operator control to ensure strategy and service differentiation.

Technical complexity:

The complexity for MORAN or MOCN implementation will depend on the 5G architecture, with an increased complexity in case of non-standalone architecture where multi-vendor X2 IoT could be required.

Resiliency consideration:

5G is natively built to offer enhanced resiliency in line with URLLC introduction. This relies on few capabilities:

- Cloud native architecture on core
- State and session separation
- Concurrent session mode
- Enhancement in the RAN compared to LTE (e.g shorter TTI, grant-free UL)
- Enhancement in Release 16 to answer verticals need (on-going work to define architecture offering >99.999% resiliency, with e.g the definition of two fully separated paths from UE to application including Coordinated Multi-Point (CoMP) in the access)

These capabilities remain valid in case of network sharing, would the right set of features be deployed in the shared RAN network over time.

9 Synchronisation of TDD networks

Question 9: IMDA would like to seek views and comments on the following:

i) The synchronisation approach for 5G TDD networks in a multi-operator environment for the 3.5 GHz and mmWave bands, specifically for the following:

Common synchronization and frame structure in 5G TDD network are key for network performance. Common frame structure eliminates the need of guard band between operators and thus maximise the utilisation of spectrum. In Nokia's view, this is critical. However, the requirement of guard band and common synchronization depends on the allocation of the actual spectrum and bandwidth.

a. Synchronised networks: the required frame alignment, compatible frame structures and BEM specifications for AAS and non-AAS base stations; and

Since TDD configuration and sub-carrier spacing (SCS) have direct impact to latency targets, it is expected that n7, n258 and n257 will follow different TDD configurations. The following TDD configurations are globally adopted by different operators.

- n78 (sub-6Ghz) may follow 30KHz SCS with frame latency of 2-5ms and ISI protection suited for macro-coverage. The following TDD configurations can be applied based on 30KHz SCS –
  - DDDDDDDSUU (5ms)
  - DDDSUDDSUU (5ms)
  - DDDSU (2.5ms)

- n258/n257 (> 6GHz) may follow 60Khz to 120KHz sub-carrier spacing with frame latency of 0.5ms to 1ms and ISI protection for small cells / micro deployments.

  The following TDD configurations can be applied based on 60KHz-120KHz SCS –
  - DDDSU (0.625ms)
  - DSUU (0.5ms)
  - DDSU (0.5ms)

DDDDDDDSUU (5ms) Frame configuration is adopted by UK as they need to sync with Existing TD LTE networks. Whereas China adopted TDD Frame configuration DDDSUDDSUU (5ms) to support long PRACH and Korea adopted DDDSU (2.5ms) TD LTE Frame configuration as there is no existing TD LTE network.

b. Unsynchronised networks: the amount of guard band, geographical separation and BEM specifications for AAS and non-AAS base stations;

Based on currently available filtering technology, guard bands and operator specific filters are necessary to enable unsynchronised operation between operators. Alternatively, geographic separation distances could be necessary, but a specific recommendation or single set of trigger values cannot be provided due to the dependency on various factors.

ECC-296 talks of at least 5MHz of guard band implemented, meaning 10 MHz between operators for unsynchronised macro network. In addition to guard band, operator specific filters would be required for the AAS case. Without such operator specific filters, ECC-296 states that “significant separation distances (up to 60km in co-channel, up to 14km in adjacent-channel) likely to be required”.

ii) The adoption of other suitable mitigation measures to mitigate interference between unsynchronised networks; and

Interference due to unsynchronised operation can be partly mitigated by adopting the following solutions individually or in combination:

- Adoption of a guard band and operator-specific filtering between the adjacent spectrum assignments associated with the interfering network and the victim network;
- Geographic separation between the interfering network and the victim network;
- Alternative network topologies to macro-cellular networks:
- Micro BS networks;
- Indoor BS networks;

- Semi-synchronised operation.

Please note that "operator specific filters" as an alternative, is not a practical option – it would require unique implementation of AAS. Adoption would require Singapore specific 5G AAS products. Due to geographical situation, a separation of interfering network might not be feasible for Singapore. Alternative network topologies will incur additional cost to operators and semi-synchronized network will impact the network performance.

iii) The need for IMDA to mandate a regulatory requirement for synchronisation across the 5G TDD networks or leave it to operators to co-ordinate their network deployment and parameters in order to reduce interference between networks.

Nokia considers that the best approach is in the first place to give the operators the opportunity to address this issue among themselves. Operator should agree to use same/common synchronization and frame structure for TDD operator. This will maximise spectrum utilization and network performance. Only in the case where this is not possible for operators to agree, IMDA should set regulations for a common synchronisation, otherwise a guard band would need to be implements losing the efficiency of the spectrum available.

10 Fixed Wireless Access

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.

Nokia welcomes IMDA position to "*allow MNOs to use existing and upcoming 5G spectrum rights for fixed-wireless services, as long as the spectrum is still primarily used for the intended mobile service*".

Even if Singapore has an impressive fibre penetration, IMDA should support all potential usage of 5G/FWA and support operators developing new usages and service.

Expected to grow by approximately 50 percent from 18.5 million to approximately 27.5 million households by 2022, FWA technologies are increasingly being used by operators to open new business opportunities and monetize new services. 5G will play a critical part in the delivery of new broadband access services and is anticipated to become 16 percent of all FWA technology deployed by 2022.[7]

[7] Ovum "Fixed Wireless Access: The Addressable Market Exceeds Previous Expectations"

Operators such as Rain[8] in South Africa, Optus[9] in Australia or Telia[10] in Finland are already offering 5G/FWA for their customers.

11 Spectrum for Industrial Usage

Singapore telecom market is vibrant and highly competitive thanks to IMDA. Nokia understands that IMDA is looking to develop a sustainable environment for the MNOs 5G business cases by allocating spectrum primarily to service providers. Nevertheless, an approach allowing private wireless networks for industrial usage could stimulate new business models and applications.

Asian Countries are taking the approach to stimulate the take-up of 5G by allocation spectrum to support industrial usage.

In Japan, MIC has reserved two blocks of spectrum (4.6—4.8 GHz and 28.2—29.1 GHz) for private 5G networks. The bands could be assigned to a specific industry or application. A working group on this spectrum has been created to further work on the usage.

In Australia, the 24.7-25.1 GHz segment will be awarded under apparatus licences. These will be limited to property and are expected to go to private, industrial or government users. They are for indoor and outdoor usage. These licences are available for wireless broadband across the country.

The 24.25-24.7 GHz part of the band will be for class licence access for wireless broadband used on private property, for instance domestic, industrial and government applications. It will be restricted to indoor use and will be available across Australia. Class licences are handed out to users on the condition they co-exist with others in the same band.

Its definition of “smaller market/local subscriber-based networks” and “uncoordinated ad hoc deployments within the confines of private premises or property’” is similar to how other regulators have anticipated demand from industry verticals in countries such as Germany, Hong Kong and Japan among others.

Nokia see large economical value in the possibilities for enterprises to invest into private wireless networks using 3GPP technologies on their premises. Additional investment into private networks by private enterprises can significantly speed up the overall 5G take-up.

Production and automation industry have gathered with Communication Service Providers (CSPs) and the vendor community in 5G-ACIA[11] to express requirements for industrial use of 3GPP technologies. Networks need to be tailored to industry needs in terms of performance, availability and reliability, privacy and security, and meeting their operational requirements. Specifically, stringent performance requirements in terms of guaranteed bandwidth and low latency at very high availability levels e.g. in wireless production control make access to licensed spectrum necessary.

8 https://www.nokia.com/about-us/news/releases/2019/02/27/mwc19-south-african-operator-rain-and-nokia-launch-countrys-first-5g-network-to-support-early-rollout-of-5g-services/
9 https://www.optus.com.au/shop/broadband/5g
10 https://www.teliacompany.com/en/news/news-articles/2019/telia-and-nokia-introduce-5g-gateway-to-finland/
11 https://www.5g-acia.org/

Thus, Nokia support individually licensed spectrum on a per location base for local private industrial use. Access to licensed spectrum for local private industrial use shall not preclude any usage scenarios in terms of how such private networks are implemented. Within the German national IT summit process, industry and administration have created a paper on such usage models including standalone private, industrial networks, shared local access networks to private networks implemented as 5G networks slices.

Therefore, we encourage IMDA to further assess and promote identification of spectrum for Private Wireless networks.

In the proposed option B, the final lot 29.1~29.5GHz could be permitted for special indoor Industry allocation only – restricted to industry zone (Class License shared). This 400MHz could be applied by CSP, or Enterprise to deliver an indoor restricted to Industrial usage/service, that is operating within the perimeter of the campus, or industrial site building. IMDA should consider this block for private usage to have an optimal use of the spectrum.

In the proposed spectrum allocation in IMDA, 50 MHz restricted (indoor) will be left unused if IMDA does not considered Nokia's Lot C proposal. For an optimal socio-economic return of the spectrum usage, IMDA should further investigate the use of private wireless network.