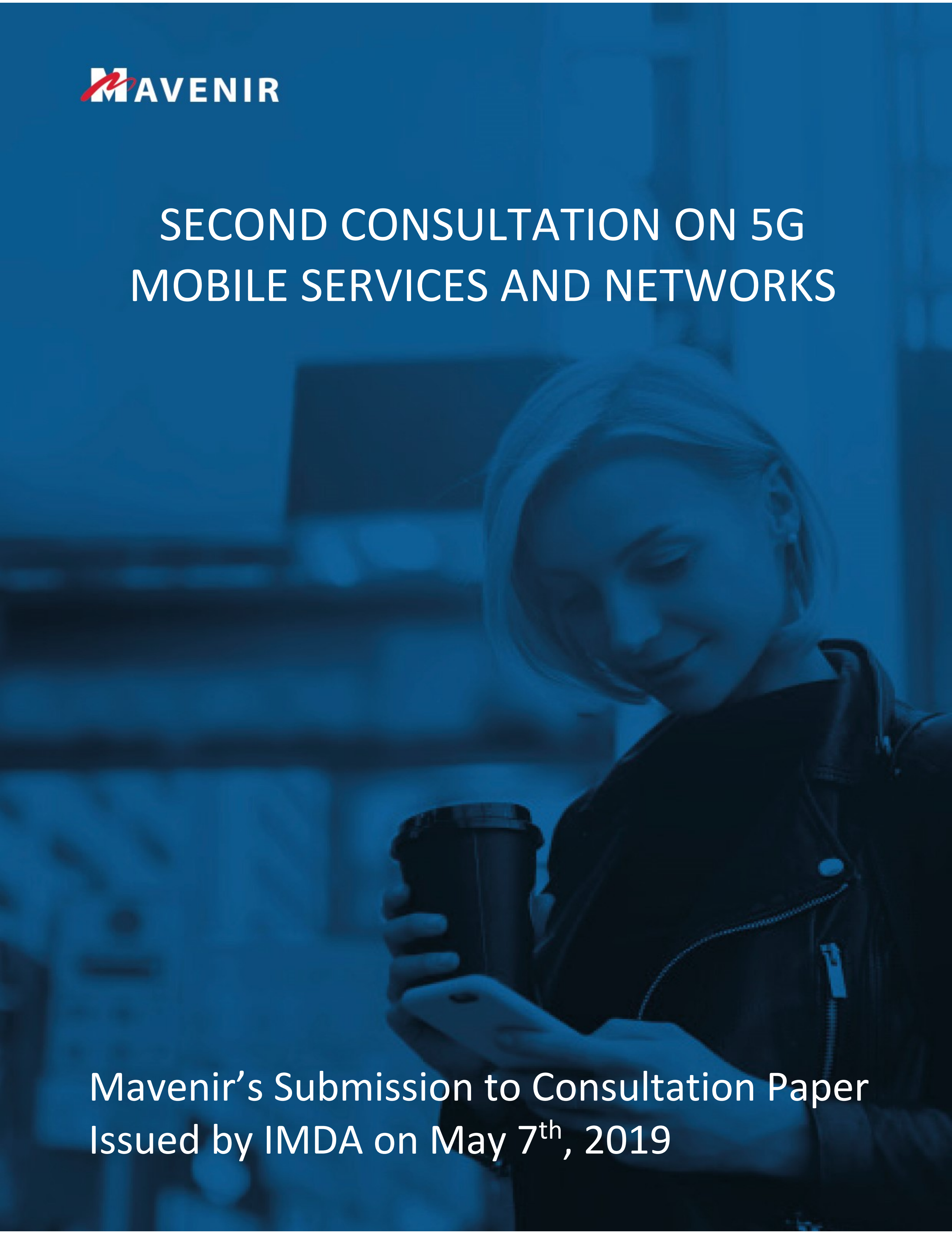

SECOND CONSULTATION ON 5G MOBILE SERVICES AND NETWORKS

Mavenir's Submission to Consultation Paper Issued by IMDA on May 7th, 2019

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Company Profile

Mavenir is the industry's only 100% Software, End-t- End MNO Infrastructure vendor with a proven track record of changing telecom economics through innovation. Mavenir is widely recognized as a leading provider of mission-critical network infrastructure software to MNOs, offering fully-virtualized, 5G-ready solutions across the mobile network infrastructure stack. We are leveraging our expertise as a disruptive innovator to open and change the current mobile ecosystem.

Mavenir offers a comprehensive, fully-virtualized solution set across Voice-over-LTE ("VoLTE"), Voice-over-WiFi ("VoWiFi"), video, voicemail, advanced messaging, security, radio access network ("RAN"), and packet core. Mavenir will enable customers to focus on service innovation and monetization, while delivering the optimization to handle the next wave of exponential traffic growth from 5G and IoT applications and services.

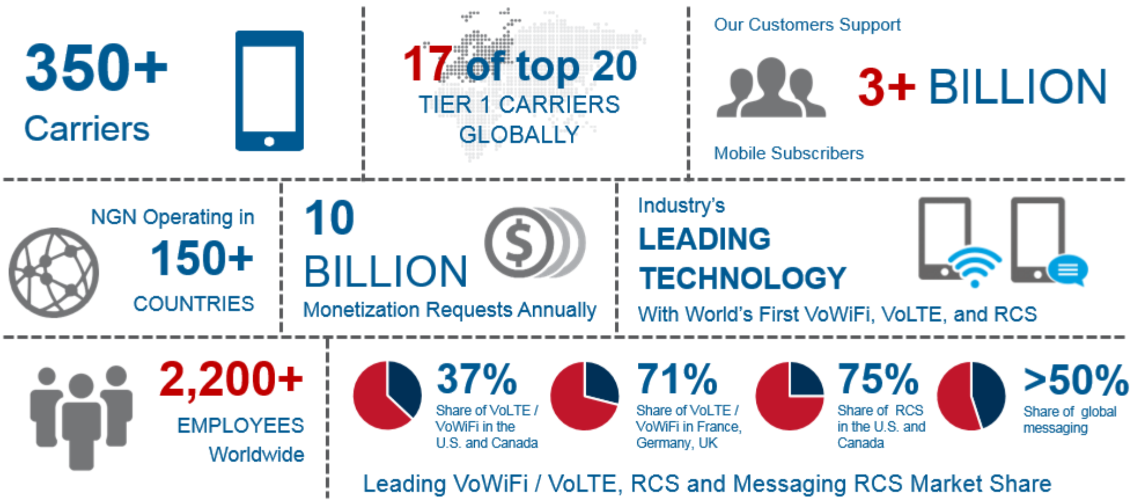
Product Portfolio: A complementary and comprehensive 5G ready, fully-virtualized NFV solution set and platform will be delivered across voicemail, VoLTE, VoWiFi, video, RCS, messaging, security, radio access and packet core

Customers at the Core: Mavenir will keep customers at the core of its strategy, with the vision of being the trusted partner of choice for CSPs as their business needs evolve

Cloud, 5G and IoT Focus: The new team will comprise over 2,000 talented people dedicated to bringing critical solutions to market that will transform and redefine the network

Operational Improvement: Mavenir will have scalable R&D centers of excellence in the United States, Israel, Czech Republic, India and China, enabling first-rate global support capabilities

Management Talent: Mavenir has a team of experienced executives, complemented by a strong Board of Directors



Mavenir in a Snapshot

Company Experience

Mavenir is a globally recognized wireless infrastructure provider which is transforming and redefining networks with in the mobile communications industry.

- 5G ready core & access networks: NFV/SDN/SDR optimized products and solutions
- Comprehensive end to end network solutions portfolio: Application Servers, IMS and Enhanced Packet Cores, Radio and Client
- Superior user experience for voice, video and advanced messaging: Rapid VoLTE/VoWiFi/RCS Adoption Rates with Improved CSAT
- Unmatched track record bringing market-leading innovation & industry firsts: 1st Commercial SMS, MMS, VoLTE, VoWiFi over IMS, RCS and Multi-Line & Multi-Device Services

Mavenir has a fully virtualized end-to-end portfolio of Voice/Video, Messaging and Mobile Core products that include IP Multimedia Subsystem (IMS), Evolved Packet Core (EPC) and Session Border Controller (SBC). Our solutions, based on the award-winning mOne® software platform, leverage NFV and SDN technologies for deployments on cloud-based infrastructure.

We have been selected by several tier one operators globally who are "early adopters" of next generation technology and are leading the industry with several "world first" commercial launches, including Voice over LTE (MetroPCS), IMS-based Voice over Wi-Fi (T-Mobile US) and Rich Communication Services Release 5 (MetroPCS).

Contents

1. Introduction

With mobile telecommunication services becoming an integral part of every industry, rather than just an industry on its own, as well as the ever-growing importance of mobile services to consumers and enterprises, and therefore mobile telecommunication services enabling digitalization of industries and the society, the importance of the regulatory framework could not be stressed enough: it ranges from facilitating economic growth to developing a prosperous nation, while ensuring fair market conditions and fueling the development of an 5G ecosystem.

Mavenir recognizes the tremendous effort that went into the preparations and issuing of the Second Consultation Paper on 5G Mobile Services and Networks – it is an honor to be invited to respond to the paper.

In this submission, Mavenir presents its responses to, or comments upon, the questions raised by IMDA it the aforementioned consultation paper.

2. Comments

1. 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.

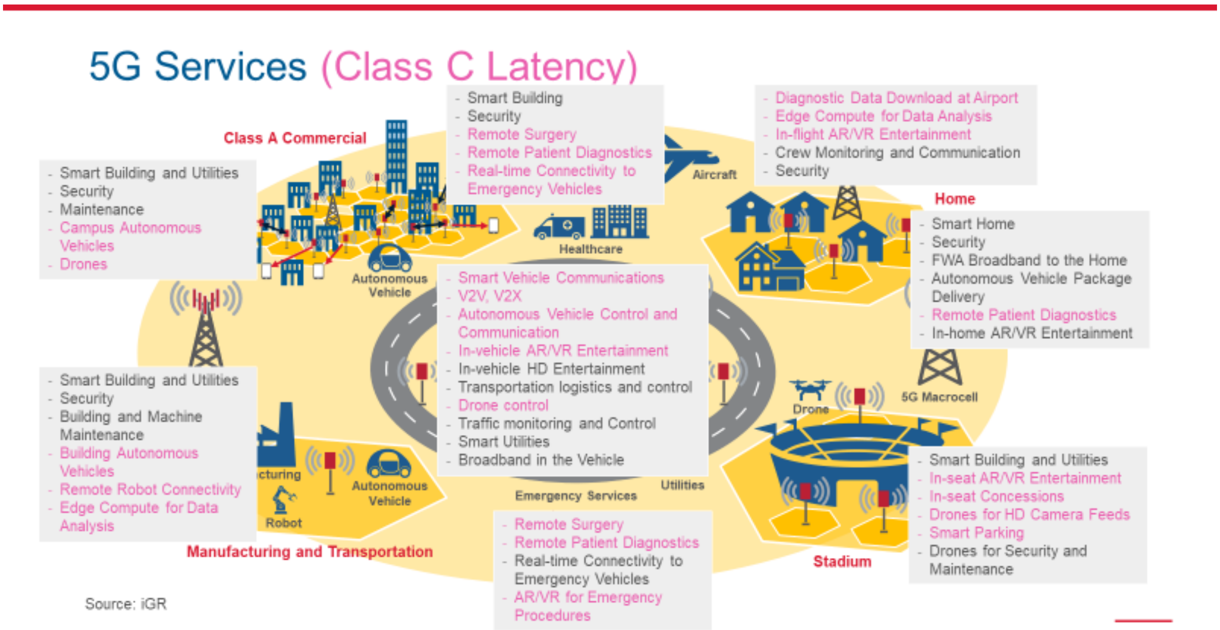
Mavenir believes that 5G networks will be virtualized and software-based, using web scale technologies. This will allow network operators to break free of lengthy vendor roadmaps and allow for rapid feature development of new competitive services, using network slicing to allow for customer and location specific services. The RAN is also going to be virtualized again requiring web scale skills in the deployment and service of the RAN network. The Radio performance will be enhanced through the use of Massive MIMO technology but essentially the skill set required will remain unchanged. The future will see an increase in demand for Web scale software engineers at an operator level. This feature development will no longer be controlled by the OEM.

2. Question 2: IMDA would like to seek views on: 1) 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;

Listed in the diagram below are a set of use cases per industry segment. Those highlighted in magenta are those requiring low latency services. The ability to build low latency services is going to be key to the success of these new industry segments

5G Services

3. Source: iGR



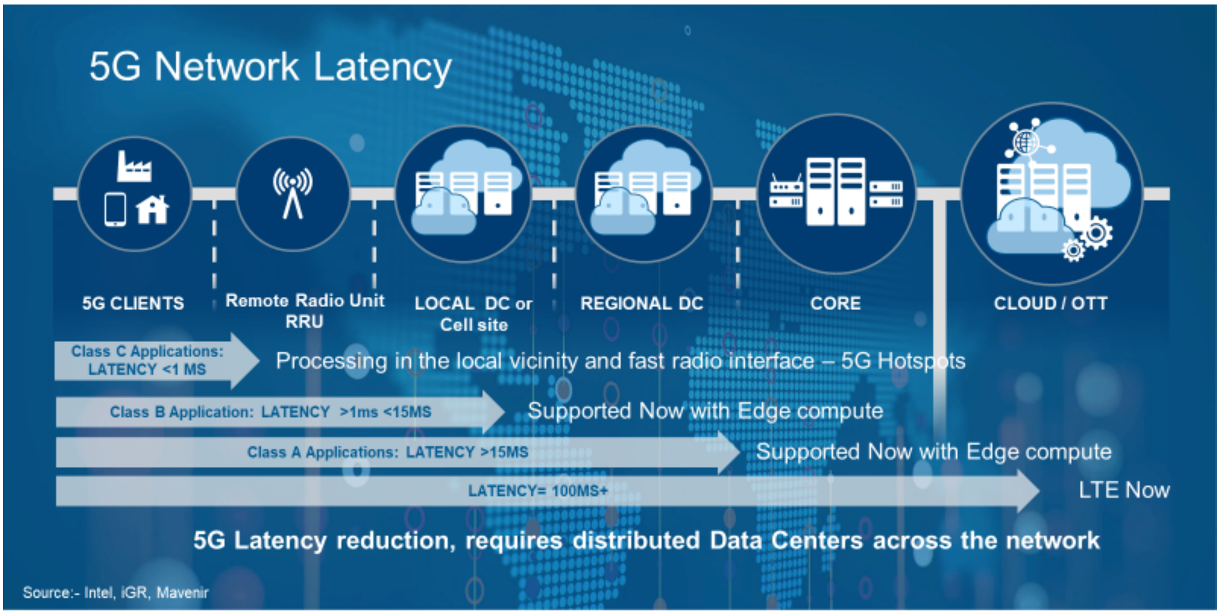
ii) Areas of government support that the industry requires in order to enable innovation and development in 5G.

Support is going to be needed from the government in the following areas which include:-

1) Construction of low latency transmission services
2) Real time application development
3) Distributed Artificial intelligence at the edge of the network
4) Open Standard support and development
5) Supporting an OpenRAN ecosystem
6) Autonomous vehicles
7) Ease of regulations for small cell deployments
8) Well defined requirements around security

The diagram below represents the positioning of the network elements and the associated latency that can be achieved at each hierarchical level.

Mavenir has also recently completed with iGR a research which paper which looks at viable business cases given the difficulty that operators have seen in generating a viable business case for 5G. We have include that which paper at the end of this document.



4. 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.

Mavenir agrees with the studies done in ITU for the guard band spacing. The ITU studies can be found in Report ITU-R S.2368. Depending on the use case (indoor small cells vs. macro), guard bands of 5 MHz to 20 MHz seem reasonable.

5. 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

Mavenir recommends IMDA follow the global deployment timelines for 5G spectrum and harmonize to the bands being developed in ITU.

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

Changing FDD spectrum in Band 7 to TDD Band 41 needs to be considered carefully as UE support is impacted and spectrum sharing between LTE and NR would be difficult.

6. 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;

Mavenir believes that it is unnecessary to build nationwide 5G networks initially. Competitive 5G services can be built with 5G hotspots as described in the attached iGR whitepaper. This will allow spectrum use for both 4G and 5G and operators to prove their services where they are needed. This is a minimal investment approach ensuring early profitability.

While recognising the importance of both 5G to industry and society, and the competiton to market development, as well as the need for cost management and commercial viability of 5G deployments, Mavenir has no comments on the number of 5G operators, or policies on network or infrastructure sharing.

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

It is advantageous to set the spectrum blocks in 100HMz blocks to allow gigabit service delivery. Otherwise, solution would look very similar to LTE and operators will not be able to provide high bandwidth, low latency services.

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

Yes 5G equipment supporting 50MHz, and other bandwidths are available.

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;

Unrestricted lots if understood correctly will allow CBRS type enterprise services and entrepreneurial competition.

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

Mavenir recommends mmWave spectrum (n257 and n261) support at 28 GHz as a first priority if possible for IMDA. The availability of devices and equipment at other bands such as 39 GHz is not yet mature.

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

Mavenir recommends harmonizing with worldwide deployments for 3.5 GHz and mmWave combinations.

7. 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;

This could be achieved in phases, with phase 1 being 5G hotspots with a percentage of key locations, hospitals, stadiums, roadways and subscribers being provide gigabit wireless coverage. The target list of commercially or strategically important key locations would be determined in a due consultation process, or prescribed by IMDA. A nationwide network should not be (initially) mandated based on area covered as this may not lead to a profitable business case.

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

Coverage and performance can simply be defined by specifying the requirements for gigabit service availability and the levels of latency expected. The percentage of population covered is not an adequate measure when considering stadiums etc where the traffic is migratory.

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

Among the service providers and vendor community, there is a consensus that 5G networks will be software-enabled, fully SDN based, with workloads distributed more heterogeneously across the network in data centres of potentially different quality to achieve a balance between data centre and transport cost, resilience and latency. The detailed design choices will determine service providers' competitiveness level.

In a much-needed ecosystem-wide engagement between stakeholders such as regulatory bodies, service providers, vendors, consumer and enterprise customers as well as various verticals, resiliency and security, in particular for mission critical and/or sensitive use cases, trust, based on security and service availability guarantees, will be a differentiating feature. The business requirements and revenue at stake will likely drive service providers to establish adequate best practices and packages.

Many countries are concerned about cybersecurity aspects and attacks for 5G. 5G will have a much richer set of devices connected to it and the infrastructure needs to be protected. Lot of bandwidth and low latency services will require increased deployment of fibre. Features such as geo redundancy and high availability will be critical to provide resiliency in a software environment and provide 5 9's service.

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

With the view of firmly entrenching communication services and connectivity at the core of industries and people's lives, as well as fuelling competition to further develop the nation thriving on digitalisation, open and fair access to 5G wholesale services is essential to enable a vivid ecosystem.

While a model that has been successfully developed and implemented for broadband services in Singapore may not be entirely applicable, the successful contestants for 5G licences should be tasked with providing open access to their networks with transparent pricing on a wholesale basis.

Well defined Infrastructure Sharing policies, while not essential to 5G wholesale services, may aid in reducing the cost of providing such services, and driving innovation through services rather than connectivity costs.

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

Mavenir has no comment to this question

i) The proposed assignment approach;

Mavenir has no comment to this question

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

Mavenir has no comment to this question

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

Mavenir has no comment to this question

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

Mavenir has no comment to this question

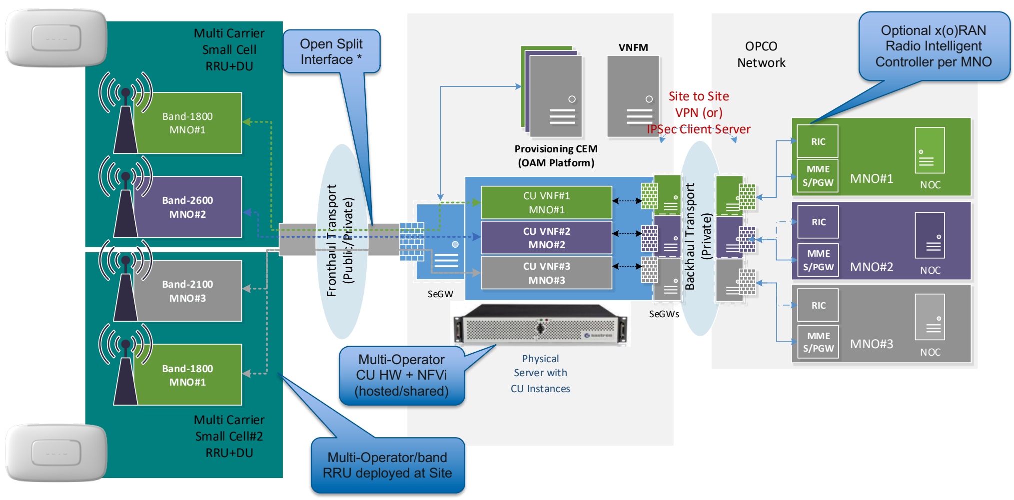
v) The enforcement and/or audit mechanisms to ensure that applicants are able to deliver on their proposals.

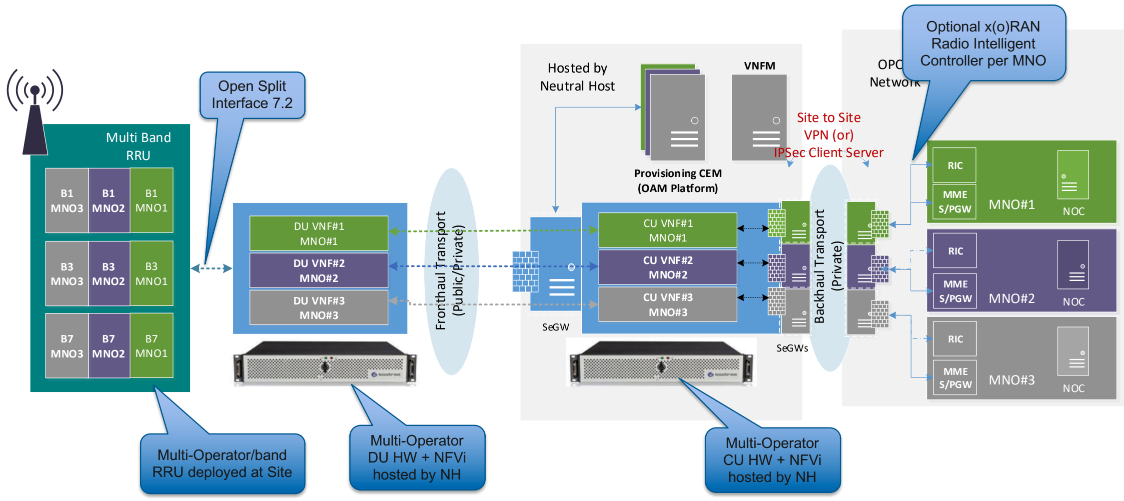
Mavenir has no comment to this question

9. 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.

Due to vast economical benefits, lower impact on urban infrastructure, shorter time-to-service and accelerated network rollout, as well as well-understood technical and commercial aspects of the infrastructure sharing at this level, Mavenir would advocate an appropriate policy framework for tower sharing / a vRAN neutral host approach, as being showcased in the UK with BT.

The following diagrams provide an overview of the vRAN solution with Small Cells Split 2, and a sampe architecture for the Split 7.2:





10. 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:

- Synchronised networks: the required frame alignment, compatible frame structures and BEM specifications for AAS and non-AAS base stations; and
- Unsynchronised networks: the amount of guard band, geographical separation and BEM specifications for AAS and non-AAS base stations;

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

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.

Mavenir agrees with the recommendations in ECC Report 296 for synchronization approaches. https://www.ecodocdb.dk/download/19d5a467-c234/ECC%20Report%20296.docx

11. 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

Fixed wireless access is a key to the success of 5G both for mmWave and Sub Six frequencies and should be encouraged.

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

In light of an excellent fibre network coverage, and Singapore's limited geographic spread, fixed-wireless services appear less relevant than in other geographies, at least for residential use.

In future, the need for higher bandwidth may potentially be more economically served by FWA than fibre network evolution, in which case the need for appropriate policies may arise.

Whether classified as fixed-wireless service, or Private 5G network, Mavenir foresees a need to leverage 5G capabilities (reliability, bandwidth and/or ultra-low-latency) to provide connectivity over a limited area with low mobility for enterprise/industry use cases such as security or robotics.

3. Conclusions

While with its geographical spread and technological advancement, Singapore presents a special case for 5G deployment and business case, the importance of a successful 5G ecosystem for societal progress cannot be stressed enough – and the appropriate regulatory framework is a key enabler.

Instead of further conclusion, the following *i*GR White Paper may provide further, usefull insights into global 5G deployments and Business Case considerations.

A real 5G Business Case that works: *5G Hotspots*

White Paper
2Q 2019

1. Executive Summary

5G is now being deployed by mobile operators around the world. With the first services coming online. But there is a problem – the initial cost to build far exceeds the expected initial revenues, such that payback on the network build is not expected until 2022 at the earliest and 2023 for any significant revenues (U.S. and Asia Pacific) – for Europe, the situation is even worse with payback not expected until 2026. And this is the best case. The good news is that there is an answer that potentially cuts the initial investment and improves the financial metrics.

5G is, in its simplest form, the next generation of wireless technology that offers mobile broadband, low latency connections and support for massive IoT connectivity. For 5G, low latency is a key differentiator from 4G LTE – the initial bandwidth capabilities of 5G NR in the same spectrum bands is similar to LTE. But low latency connectivity is *only* enabled by 5G. As such, new 5G revenue-generating applications and services will have to utilize low latency to show value.

When an operator first deploys LTE or 5G (or any new technology family), the initial build is designed simply to cover the required area: operators first build to cover as many POPs as possible with the fewest cell sites possible. Once the 5G subscriber base starts to grow, more devices become available and usage of the network increases, then the operator increases the network capacity and attempts to fill in the dead spots in the original network. *iG*R has modeled the 5G build costs (the cost to deploy the network, not operate it) for multiple regions across the world for 2018 to 2027 – this is the cost to build out a wide-area 5G network at scale, to meet the demand for mobile data:

- U.S. $64.6B total
- Europe $100.2B total
- Asia Pacific $200.6B total.

Taking the approach of building out the wide-area network as the revenue sources are also being developed results in the long payback period.

The net effect of this analysis is that, across the world, mobile operators will invest in 5G for years before seeing any return – the fastest time that revenue exceeds the network investment and operating cost is 2023, five years after the start of the investment. And this is the ***best*** case in terms of revenue and returns, assuming that 5G apps and services generate revenues immediately and that consumers see the value of 5G.

The business case that works is to initially only build 5G 'hotspots' where the mobile operators need low latency to provide value-added services. 5G RAN hotspots, supported by edge compute, would provide low-latency services only where needed, thereby reducing build and operating costs but still providing 5G services.

What are the expected savings using this approach? Obviously, 5G network deployment and operating costs vary depending on the extent of the build but in general, according to *iG*R's analysis, if a mobile operator deploys hotspots covering 10 percent of a wide-area build, the costs will reduce by 90 percent compared to the wire-area network. Note that this still means 5G service will be available in select areas and will still generate revenue, leaving wide-area coverage to the LTE network. But, importantly, the initial 5G investment is far lower when the new 5G revenue sources are still being developed.

It is important that this approach can be used in any region and country, and that the corresponding savings can therefore be realized anywhere. 5G is a global standard (as LTE is) and therefore the architecture the mobile operators deploy is essentially the same across the world.

5G hotspot deployment is the business case that works for 5G. Using the strategy of quickly building 5G where needed, benefiting from virtualization and edge computing allows the mobile operator to offer 5G services only where needed and quickly develop new revenues. As the 5G revenues build, 5G coverage can be expanded as needed, leaving wide-area coverage to the 4G LTE network (which addresses the needs of the majority of subscribers).

2. What is 5G and what does it enable?

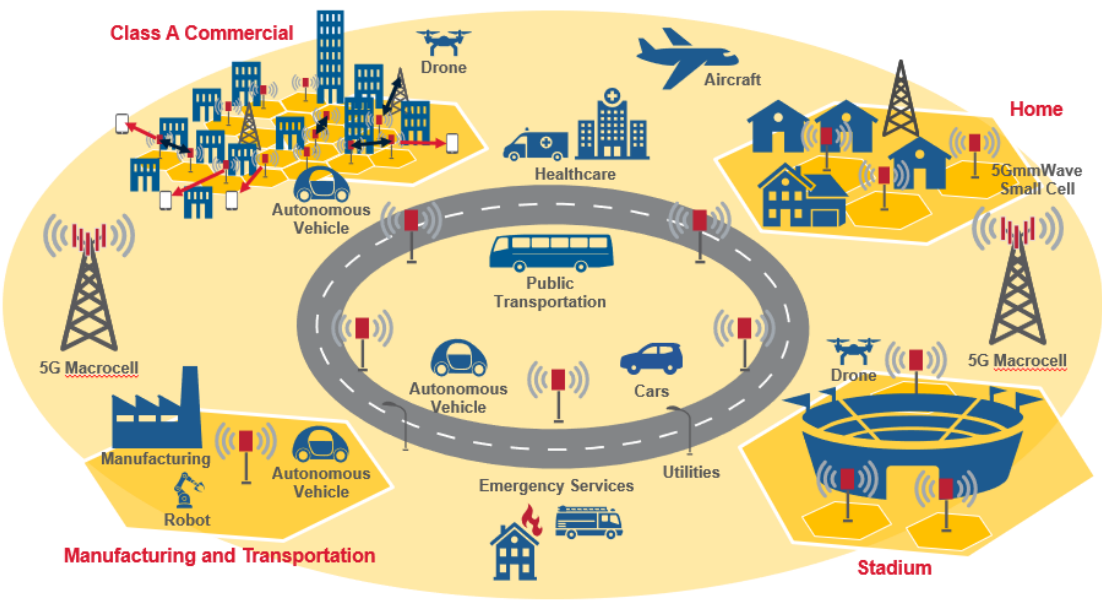
5G is, in its simplest form, the next generation of wireless technology that offers mobile broadband, low latency connections and support for massive IoT connectivity. 5G technologies improve on LTE (classed as 4G) through the use of an improved air interface, new network architectures and a new packet core. Technically, 5G is defined as Release 15 of the 3GPP standards, although many people consider Release 16 to be 'true' 5G since this includes the new core with support for massive IoT.

1.1 Traditional view of 5G implementation

Traditionally, the initial view of 5G implementation is simply to migrate the exiting 4G LTE networks to Release 15 5G and beyond. This assumes that the macrocells will move to Release 15 NR, small cells will be upgraded and that the 4G EPC will be replaced with the 5G new core, defined in Release 16. The assumption is that, just as happened in the 3G to 4G evolution, the first deployments would be in major metro markets, before moving to suburban and rural areas.

The consumer would then experience 5G in areas of highest data usage, with 4G LTE everywhere else. But, as *iG*R will show in this paper, this involves significant cost over the next decade. Figure 1 shows the traditional implementation of the 5G network architecture and associated applications.

1.1.1 Figure 1: Traditional 5G network architecture and applications implementation



Source: *iG*R, 2019

In order to extract the maximum value from 5G, the industry will need to identify and implement high bandwidth/low latency apps and services. Some of these are shown in the figure above. Note that the typical 5G applications make use of remote control of devices, drones or vehicles, augmented reality/virtual reality for both consumer and business, as well as in industry, and high bandwidth services to the home and business.

For 5G, low latency is a key differentiator from 4G LTE – the initial bandwidth capabilities of 5G NR in the same spectrum bands is similar to LTE. But low latency connectivity is only enabled by 5G. The question then becomes what services can 5G enable and which of these can be monetized?

2.1 5G Revenues sources

It is important to understand that the shift to 5G will require new business models and that revenue will have to come from sources that the mobile operators have not used before. Simply relying on subscription revenue from end users will not be sufficient. *iG*R expects six major sources of revenue that mobile operators can depend upon in the 5G era:

1) 5G Mobile Broadband Service

*iG*R expects that the mobile operators will offer mobile broadband services for 5G using models that are similar to the ones used for LTE today. That is, the consumer will either buy an 'allowance bucket' giving a certain amount of data per month or will have an 'unlimited' plan. In some cases, the operator may throttle the speed of mobile users on 'unlimited' plans when there is high usage on the network.

*iG*R assumes that consumers will initially be willing to pay slightly more for 5G than they currently do for LTE. This assumption is partly based on *iG*R's recent consumer research in March 2018 and January 2019.

2) 5G IoT

Potential revenues from IoT on 5G networks also exist for mobile operators. The current LTE business model includes a very low price per device on an LTE-M or NB-IoT network. For example, major U.S. operators charge between $0.50 per month per device and $0.99 per month per device. *iG*R expects that operators will be able to charge more per device for those on the 5G network, as the network will offer extremely low latency and higher bandwidth, which will be valuable for certain specific applications.

3) 5G Fixed Wireless Access

Fixed Wireless Access, based on the 28 GHz and 39 GHz bands, is a significant part of the 5G discussion. When wireless network providers provide fixed wireless broadband services, it could be a disruptive technology to the Internet industry. This product will be able to provide Internet access comparable to existing broadband services, without all of the costs and hassle associated with connecting fiber to homes. And of course, this provides an additional revenue source for 5G network operators.

4) Advertising

*iG*R believes advertising revenue for the mobile operators will come from four main sources:

- Ads viewed as the 5G consumer accesses Web pages and uses the Internet. This follows the well-established models seen today.

- Ads for viewing video content. This may be a banner ad at the bottom of the video or a short video ad before (or during) the main content. Again, these business models are well established.

- Product placement in video content (another well-established business today).

- Sponsored content, in the form of 'brought to you by…'.

Note that there is little that is truly new here; the mobile operators merely need to emulate what is happening today on the Web, in applications, in movies and on TV shows. Certainly, some consumers will use ad blockers, as they do today, and not all consumers will be amenable to advertising. But *iG*R believes a sufficient percentage of the user base will be addressable to provide meaningful revenue to the operator.

5) Entertainment

In addition to advertising revenue from entertainment, mobile operators can also offer subscriptions to various entertainment content over their 5G network. AT&T's DirecTV Now (allowing access to DirecTV content via mobile devices or third-party broadband) was the first example of a mobile operator offering a subscription-based entertainment content service. T-Mobile announced in December 2017 that they had agreed to acquire Layer3TV and is using the company's technology for their new recently launched TV service, TVision Home.

6) Network slicing

Network slicing offers a potentially great source of new revenue for the 5G service provider but at present *iG*R does not see any way to model this. Simply, the business models for network slicing have yet to be defined.

Network slicing occurs when a mobile operator dedicates network resources to a specific application, service, group of users or company. Network slicing is still in its infancy. When asked about how the service will be priced, mobile operators and vendors simply respond 'value based'. The industry has yet to define the business models for network slicing, which parts of the ecosystem get what share of the revenue, and how the service will be provided.

3. Cost to Build 5G Networks

Determining the exact cost of mobile networks is very difficult due to the many variables that the mobile operator must take into account when building a network. When an operator first deploys LTE or 5G (or any new technology family), the initial build is designed simply to cover the required area: operators first build to cover as many POPs as possible with the fewest cell sites possible.

Once the LTE or 5G subscriber base starts to grow, more devices become available and usage of the network increases, then the operator increases the network capacity and attempts to fill in the dead spots in the original network. Operators are continually balancing their network build and operating costs between coverage and capacity. The engineers strive to provide sufficient coverage to be competitive and sufficient capacity to meet the needs of the growing subscriber base, while minimizing unnecessary spending.

3.1 Methodology and Assumptions

*iG*R's mobile network build cost model is based on the amount of data the network is able to support and deliver. The build cost model is based on the cost required to add 1 GB of data capacity to the network and then operate that capacity. This white paper expands the model in order to estimate the total infrastructure opportunity for 5G in the U.S., Europe and Asia Pacific, estimating the costs associated with converting the RAN to 5G, densification and data center enhancements.

With respect to the cost forecast itself, *iG*R's model is divided into two main time-based sections:

- Transition Era: 2018-2021, which includes the ongoing implementation of SDN and NFV, deployment of MTC / IoT, ongoing centralization of the RAN and ongoing introduction of new spectrum assets below 6 GHz and limited introduction of centimeter and millimeter wave bands for non-backhaul deployments (but not including the cost of the spectrum itself). This phase also includes the implementation of Release 15 Non-Standalone 5G NR.
- 5G Era: 2021-2027 (and beyond) includes further implementation of SDN, NFV, MTC/IoT and RAN virtualization/centralization, use of centimeter wave and millimeter wave bands for direct-to-subscriber voice/data communications, in addition to backhaul and the emergence of the first truly integrated carriers whose customers access the same services/content in a network agnostic fashion.

4.1 Calculating the cost to build 5G

The first step in the model is to take the number of GBytes of data used per month per connection (from *iG*R's existing research) and calculate the total amount of mobile traffic the network has to support. Today, vast majority of traffic is LTE, but 5G data demand will increase as more devices are purchased and networks become more common. This first step therefore shows the network capacity needed for 4G LTE and for 5G.

The next step is to apply the capital build cost per GB to the 4G and 5G capacity numbers to get the total cost of network. Note that the 4G and 5G costs per GB are different due to the maturity of the technology:

- The initial cost per GB for 5G is very high, since this is effectively a greenfield network
- As more network is deployed and more subscribers use the network, the cost of adding incremental 5G capacity is reduced
- Also, the cost reduces as 5G equipment moves down the cost curve due to competition, development, scale, etc.

So, as demand for 5G data increases, increasing amounts are spent on adding network capacity, but the cost per GB of capacity decreases. As a result:

- Bigger networks are more efficient to build when there is high demand for data capacity
- But big networks are very inefficient to build when there are few connections or devices that are able to use the network.

*iG*R has modeled the 5G build costs (the cost to deploy the network, not operate it) for multiple regions across the world for 2018 to 2027 – this is the cost to build out a wide-area 5G network at scale, to meet the demand for mobile data:

- U.S. $64.6B total
- Europe $100.2B total
- Asia Pacific $200.6B total.

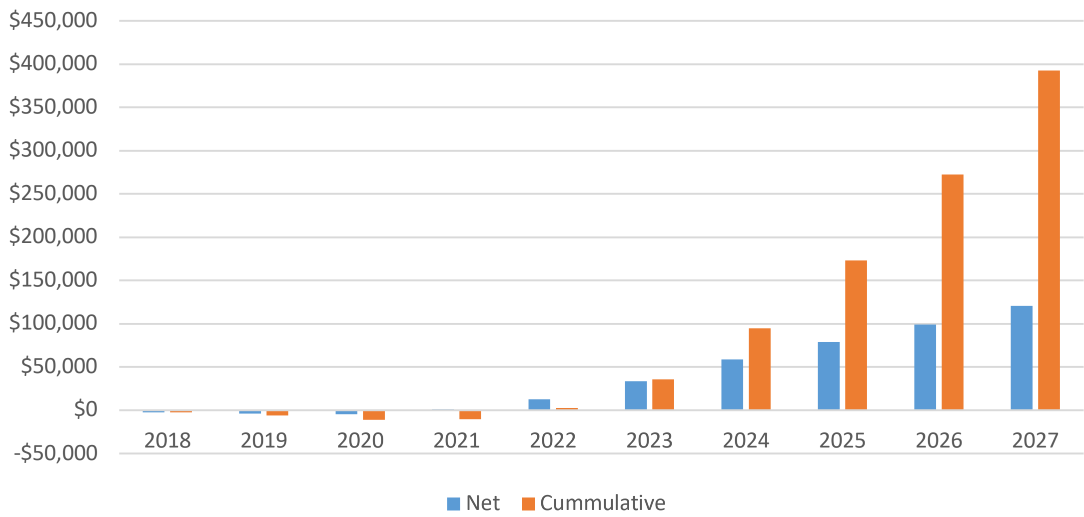
4. When does 5G Revenue – Build turn positive?

The next question is, therefore, when can the mobile operators make money from their 5G investment? Simply, this can be viewed as when the 5G revenues exceed the 5G investment to build the network – this calculation is shown in the chart below for the U.S., Europe and Asia Pacific combined.

The following charts show the net difference between 5G revenue and 5G build and operating cost for the U.S., Europe and Asia Pacific regions. The source for the underlying data for these charts is *iG*R's extensive ongoing mobile network infrastructure cost research and 5G revenue research.

Looking at Figure 2, in the U.S., the *net* revenues exceed costs for the first time in 2022 (blue bar). But the *cumulative* 5G investment + operating costs (red bar) is not exceeded by *cumulative* 5G revenues until 2023, with no significant difference until 2024. Therefore, this means that, after starting their 5G investments in 2018, the U.S. mobile operators cannot expect to see payback until 2023 at the earliest and until 2024 in any meaningful amount.

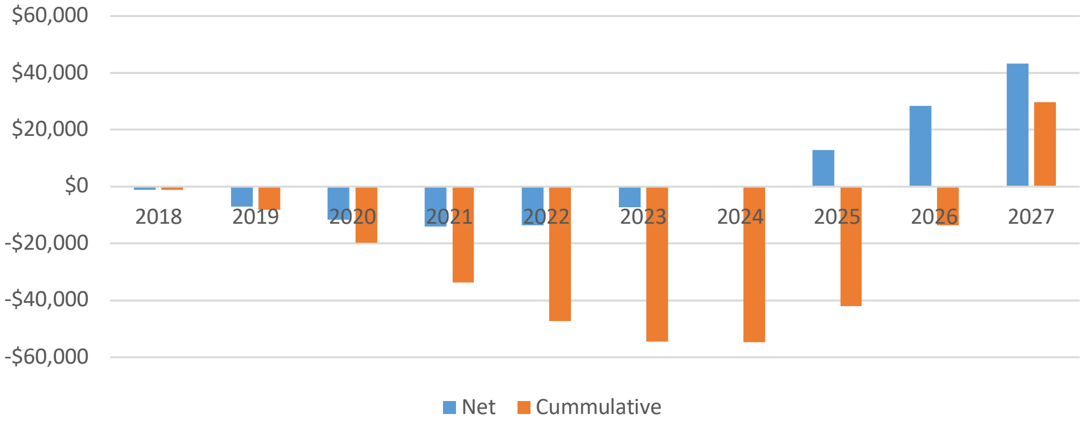
2.1.1 Figure 2: U.S. 5G Revenue – Build Cost – Opex ($M)



Source: *iG*R, 2019

The next chart (Figure 3) shows the situation for Europe – it is even worse. Now, the *net* 5G revenues do not exceed *net* 5G build and operating costs until 2025 (blue bar). And the *cumulative* 5G investment + operating costs (red bar) do not exceed *cumulative* 5G revenues until 2027, the very end of the forecast period. This means that European mobile operators will have invested in 5G for nearly *ten years* before seeing any returns.

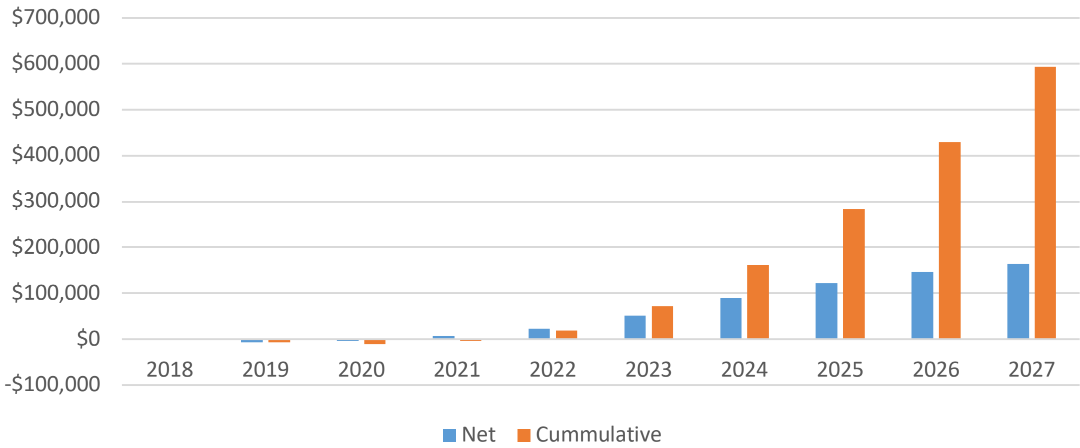
3.1.1 Figure 3: Europe 5G Revenue – Build Cost – Opex ($M)



Source: *iGR*, 2019

Finally, Figure 4 shows the same calculations for the Asia Pacific region. Due to the size of the region, the variation in the markets and the size of a few large populations (China and India), the prospects for 5G are a little better than for Europe. The *net* 5G revenues just exceed *net* 5G build and operating costs in 2021 (but it is marginal) and not by any meaningful amount until 2023 (blue bar). And the *cumulative* 5G investment + operating costs (red bar) do not significantly exceed *cumulative* 5G revenues until 2023.

4.1.1 Figure 4: Asia Pacific 5G Revenue – Build Cost – Opex ($M)



Source: *iGR*, 2019

It is important to understand that this is ***BEST*** case – the model assumes that 5G revenues start as soon as the networks are launched and subscribers start using the service. Some revenues will take longer to develop (5G IoT, for example), while 5G mobile broadband will hit the bottom line immediately.

The model also assumes that consumers see the value in 5G and are willing to pay for new applications and services. Based on *iGR*'s initial consumer research on this subject, we believe the mobile operators and the industry will be able to differentiate services and provide value for a core group of consumers.

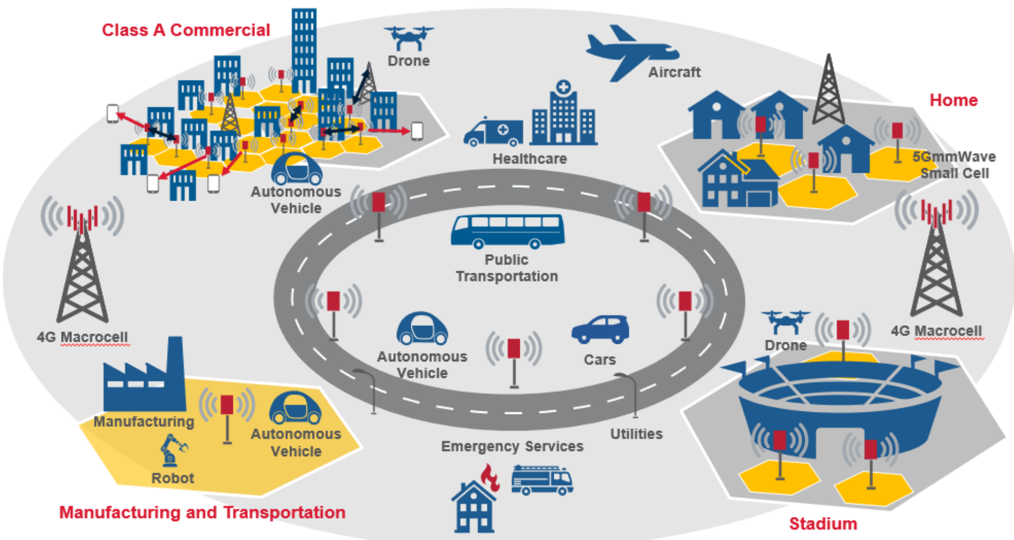
5. The 5G business case that works

The net effect of this analysis is that, across the world, mobile operators will invest in 5G for years before seeing any return – the fastest time that revenue exceeds the network investment and operating cost is 2023, five years after the start of the investment. And remember this is the ***best*** case in terms of revenue and returns, assuming that 5G apps and services generate revenues immediately and that consumers see the value of 5G.

So the question is how can the mobile operators minimize the risk of building 5G networks, especially in the early years, while also providing value to consumers?

One solution is shown in the figure below – start with building 5G hotspots (shown in yellow) to meet specific needs, applications, customers, etc and maximize the current investment in LTE (shown in gray) to provide wide-area high bandwidth coverage. This architecture is therefore the first step leading to full 5G deployment if needed.

5.1.1 Figure 5: 4G and 5G network architecture – the interim step with 5G Hotspots



Source: *i*GR, 2019

5.1 5G Hotspots

The concept of an initial 5G build is to build 'hotspots' of 5G where needed, for example in industrial sites, residential areas; malls, etc. essentially, areas of high traffic and/or high value for 5G. The operator would then need to promote 5G in those areas and maximize the benefit from the 5G applications and services, to establish a proven revenue stream.

The macro network can then be upgraded to 5G as needed, as maintenance/updates dictate and to meet the increasing demand for 5G data capacity in that market. The impact of this approach is a faster return on the initial 5G build investment, which then provides supporting data for continued 5G build, as well as, obviously, improved financials.

6.1 Can Edge Compute be leveraged for 5G New Core?

Part of the 5G build investment is obviously in the new 5G Core, replacing the existing LTE EPC. While deploying 5G, mobile operators are also investing in Edge Computing to reduce latency, etc – these investments are already in progress, providing hardware and software to support various apps and services.

Can this edge computing investment be leveraged to support the 5G 'hotspots'? The edge computing architecture uses a distributed, virtualized environment that is deployed on off-the-shelf hardware. This is the same architecture that the 5G new core will use and therefore an opportunity to co-locate the solutions and reduce deployment costs.

Consider that, according to *iG*R's forecasts, the mobile operators, globally, will have to spend $25.6B on 5G New Core between 2018 – 2023 if building out network-wide 5G. This spending is split among the various regions of the world according to 5G investment, with Asia Pacific responsible for the largest 5G New Core spending.

But the spending to put edge computing in the mobile network during this time is far less, at $387 million globally. Thus, if the edge computing architecture can be leveraged to support 5G, the potential savings are significant.

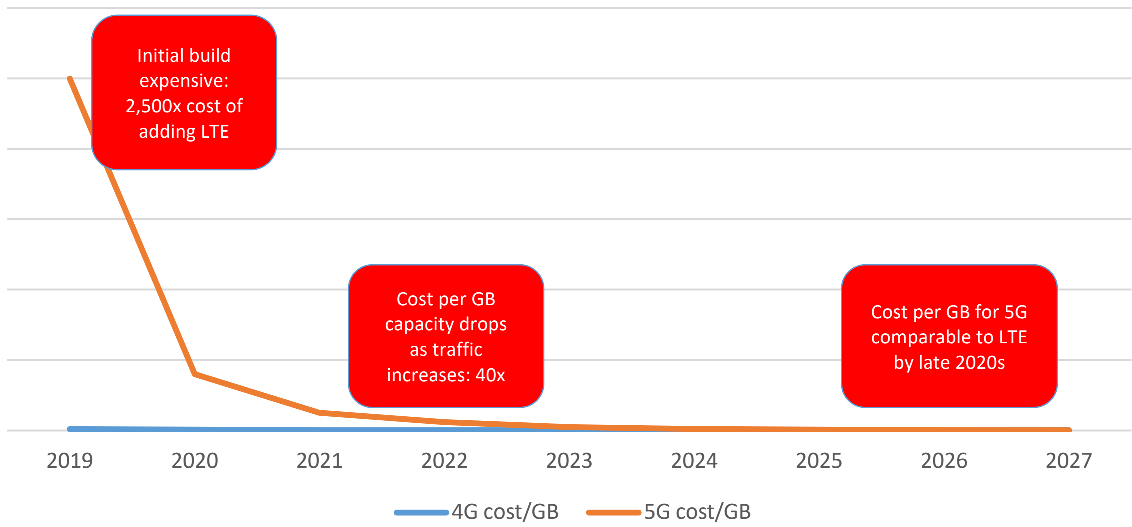
6. Summary/Conclusion

As this paper discusses, building a wide-area 5G network can be very expensive, perhaps prohibitively so. When the uncertainty regarding new 5G revenue sources is taken into account, it is clear that an alternative approach is needed. This is where the concept of an initial 5G build comes in: build 'hotspots' of 5G where needed, in areas of high traffic and/or high value for 5G. The operator would then need to promote 5G in those areas and maximize the benefit from the 5G applications and services, to establish a proven revenue stream.

The macro network can then be upgraded to 5G as needed, as maintenance/updates dictate and to meet the increasing demand for 5G data capacity in that market. The impact of this approach is a faster return on the initial 5G build investment, which then provides supporting data for continued 5G build, as well as, obviously, improved financials.

The following chart shows the challenge for the MNOs with 5G – to build capacity as fast as possible to reduce the cost per GB for the network deployment. Note that the initial build is expensive on a per GB basis at approximately 2,500 times the cost of LTE. But as more 5G capacity is added, the cost per GB drops, such that by the late 2020s, *iG*R forecasts the 5G cost per GB to be comparable to LTE.

6.1.1 Figure 6: Reduced cost for 5G build per GB



Source: *iG*R, 2019

How much would the MNOs be able to save by deploying 5G hotpots? Consider that, according to *iG*R's forecasts, the mobile operators will have to spend $25.6B globally on 5G New Core between 2018 – 2023 if building out network-wide 5G. But the spending to put edge computing in the mobile network during this time is far less, at $387 million (again a global total). Thus, if the edge computing architecture can be leveraged to support the 5G hotspots, the potential savings are significant. Depending on the cost of the software solution deployed for 5G New Core (deployments will vary by operator depending on need), the savings in 5G New Core spending by using an edge compute architecture to support small 5G hotspots could be up to 95 percent.

The savings in RAN spending will vary according to the MNO's initial plans for 5G. But clearly, if an operator decides to initially deploy 5G RAN covering 10 percent of the overall planned build, the spending will be 10 percent or less than the cost to cover the entire market. The MNO can therefore selectively deploy 5G RAN hotspots, supported by edge compute, and save approximately 90 percent of the build and operating cost compared to deploying 5G en masse.

If the 5G 'islands' approach is applied to the 5G cost and revenue models shown previously in figures 2, 3 and 4, then payback time improves significantly. Table 1 shows, for each region, when the 5G revenues exceed the 5G build and operating costs – the 'Traditional approach' refers to the model shown previously, while the '5G islands approach' shows the payback time assuming an *initial* RAN buildout of 10 percent. Clearly, the benefits are marked – in the U.S. for example, the payback time improves from 2022 (for the net savings) and 2023 (for the cumulative benefit) to 2020 – improvements of two and three years respectively.

7.1.1 Table 1: Payback period for Traditional and 5G 'islands' approach

		Traditional approach	5G islands approach
U.S.	Net	2022	2020
	Cumulative	2023	2020
Europe	Net	2025	2022
	Cumulative	2027	2024
Asia Pacific	Net	2021	2020
	Cumulative	2023	2020

Payback period is when 5G revenues exceed 5G build and operating costs

'Net' shows when revenues exceed costs on an annual basis

'Cumulative' shows when revenues exceed costs cumulatively from the start of the period

Source: *iG*R, 2019

Using this approach of deploying 5G hotspots supported by edge compute also has an important secondary benefit: this approach allows the MNOs time to develop the new revenue sources, build consumer awareness and, importantly, increase the penetration of 5G-capable devices in the subscriber base. Once the 5G market reaches critical mass, wide-area deployments can be increased as required, providing the network to support the 5G revenue stream.

7. Methodology

*iG*R relied on the following sources when writing this whitepaper:

- *iG*R's 5G Revenue Forecasts
    - U.S. 5G Revenues, 2017-2027
    - Europe 5G Revenues, 2019 – 2027
    - Asia Pacific 5G Revenues, 2019 - 2027
- *iG*R's Infrastructure build forecasts
    - U.S. Mobile Network Infrastructure Spending Forecast, 2017-2027
    - Europe Mobile Network Infrastructure Spending Forecast, 2017-2027
    - Asia Pacific Mobile Network Infrastructure Spending Forecast, 2017-2027
- *iG*R's Edge Compute Operator build forecasts
    - U.S. Mobile Operator Edge Computing Spending Forecast, 2018-2023
    - Western European Mobile Operator Edge Computing Spending Forecast, 2018-2023
    - Asia Pacific numbers modeled but not published
- All reports on *iG*R website (https://igr-inc.com/advisory-subscription-services/research-catalog)

7.1 Disclaimer

The opinions expressed in this white paper are those of *iG*R and do not reflect the opinions of the companies or organizations referenced in this paper. All research was conducted exclusively and independently by *IGR.*

8.1 About *iG*R

*iG*R is a market strategy consultancy focused on the wireless and mobile communications industry. Founded by Iain Gillott, one of the wireless industry's leading analysts, we research and analyze the impact new wireless and mobile technologies will have on the industry, on vendors' competitive positioning, and on our clients' strategic business plans.

A more complete profile of the company can be found at http://www.iGR-inc.com/.