CICRA - 5G spectrum

Response to 'Draft Statement of Intent'

Submitted by the:
'Guernsey Investment Fund' in partnership with Airfi Networks

July 13th, 2019 v0.9

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About us

Guernsey Investment Fund

Guernsey Investment Fund PCC Limited ("GIF") was launched in February 2018 with the aim of achieving long term capital growth and a commercial rate of return for shareholders. GIF and each of its cells intends to do this through investments which have a Bailiwick of Guernsey focus, or which may benefit directly or indirectly the development of the Bailiwick.

GIF intends to form a number of protected cells, with the technology and innovation cell being the first to launch. Property and infrastructure cells are being considered for the future. The intention is that each cell will be fully invested within five years with an intended realisation within 10 years.

GIF is a registered closed-ended collective investment scheme, incorporated as a protected cell company limited by shares. It is established in Guernsey and regulated by the Guernsey Financial Services Commission.

Airfi Networks

Airfi Networks is a global company, headquartered in Guernsey with offices in London, San Francisco and Atlanta in the United States. The founders are experienced in the areas of telecommunications, systems integration and consumer electronics industries. Via its newly built platform, the goal of the business is to make the process of launching and managing cellular enabled connected devices as easy as possible on 3G/4G/5G networks for brands and manufacturers. The founders have extensive experience with 2G, 3G and 4G technologies in areas of network rollout, management and operations.

Airfi Networks is the technology advisor to GIF on this venture.

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Executive Summary

This is a GIF document produced in partnership with Airfi Networks in response to the CICRA 5G Spectrum: Draft Statement of Intent published 3rd May 2019. This document provides answers to questions posed with supporting information.

GIF is seeking to work with local governments and operators in order to advise, finance, then facilitate the construction and management of a single wholesale only mobile network on both Guernsey and Jersey. Airfi Networks is advising on the technological, business modelling and operational aspects of the venture.

The network could be leased to operators thus removing the need for the them to pay out large capital sums on network infrastructure. In broad terms, a mechanism by which this may be delivered is to purchase an operator's network and lease it back. This 'lease back' model becomes viable should two or more operators contract to leaseback the service. GIF is seeking to ensure a cost-plus single digit annual return; thus, the more operators that join the scheme, the lower the costs for all.

[redacted]

The new 'Netco' could become a wholesale only mobile infrastructure provider for 3G/4G/5G services.

From a government perspective, a single network should be preferable on a small island due to environmental concerns in areas of mast proliferation, the public's concern regarding perceived health issues and a fairer use of the spectrum assets. [redacted]

In summary, the single network concept will provide the Islands' Governments with:-

1. An environmentally low impact single mobile network vs the three-network model today
2. Mobile services that provides the citizens and businesses on the islands with the best possible performance at the most competitive rates
3. A mobile network that addresses any potential security concerns
4. Fairer use of spectrum assets; and
5. An open technology architecture to attract new services to the island.

To quote the International Telecommunications Union "At the highest level, 5G is an opportunity for policy-makers to empower citizens and businesses. 5G will play a key role in supporting governments and policy-makers in transforming their cities into smart cities, allowing citizens and communities to realize and participate in the socio-economic benefits delivered by an advanced, data-intensive, digital economy."

Further information on statements made in this submission is available to CICRA.

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Considerations

An independent mobile wholesale only network owned and operated on behalf of the Islands can deliver significant benefits [redacted]

Independent investment in new 5G technologies and commercial innovations can accelerate the rollout of services benefiting business and consumers, placing Guernsey in particular at the forefront of a truly connected society.

When developing a 5G strategy for the islands, consideration has to be given to several factors, including, but not limited to:

- **Danger of increasing the "digital divide" -** the more densely populated urban areas will always be the most commercially attractive, while the business case for investing in 5G, especially in the early stages of 5G deployment in more sparsely populated rural areas will remain challenging for existing operators. One shared network has a compelling business case to provide high speed services to all areas.
- **The case to accelerate deployment -** the need for 5G is immediate for Guernsey when benchmarking broadband speeds with other markets. Currently Guernsey stands at 54th in the world for internet access speeds. See Q1 answers in the document.
- **Policy makers can make a difference -** where demand exists, policy makers can use a range of legal and regulatory actions to facilitate 5G deployment, including:
  - **Spectrum** - in order to deliver the full benefits of 5G, sufficient spectrum in desirable frequency bands needs to be made available.
  - **Fibre Investment -** 5G radio base stations will need enhanced backhaul capability. Consideration should be given to deploying a new stand-alone fibre "back-bone" at least to key hub sites or incentivising existing operators to "open-up" existing fibre capacity on a commercially attractive basis.
  - **Access Costs -** ensure that only reasonable fees are levied to deploy small-cell radio equipment on to street furniture.
  - **Off-Island Link Capacity -** there needs to be a guarantee of sufficient off-island link capacity to cope with the anticipated massive growth in traffic. Guernsey is using less than 10% of the available backhaul capability due to high cost of wholesale / retail connectivity to UK/France. Jersey is probably a similar ratio given the additional fibre's it owns on the Liberty cable vs Sure's Hugo cable.
  - **Planning -** planning consents were previously granted on a site by site basis thus disrupting the Islands' overall radio architecture, delaying implementation and creating areas of poor performance. In the past there has been an un-intentioned naivety by planning to specify lower mast heights by 1-2m in some areas - thus leading to poorer coverage and additional infill sites. 5G radio planning is more complex than the 2G/3G/4G standards due to the additional radio transmission demands required to deliver a low latency, high bandwidth service with performance guarantees. The Islands' planning departments should take a holistic view of the Islands' radio planning requirements to ensure a fully optimised network is designed in order create a minimal number of sites with maximum coverage. A one stop planning process is recommended.

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Answers to questions posed by CICRA

Section 3.6, Page 6

Q1	What '5G services' foresee could be delivered through this allocation of spectrum? What economic and social benefits will these bring to the Channel Islands?
Ans	## High Speed Broadband With the rollout of a high performing, island-wide 5G network, Guernsey can "leap-frog" the requirement for expensive, slow to rollout, un-competitive, highly disruptive rollout of fibre-to-the-home technologies and provide high-speed internet access to the communities and businesses of Guernsey, in a very reduced timescale. On Jersey 5G offers a potentially competitive and more flexible alternative to businesses and consumers over fibre for many applications. Fibre has an important role to play on both Islands for backhaul services and for businesses running data intensive systems. With the appetite and resources to develop the other pillars of a future digital economy, 5G can put Guernsey in particular on a level playing field with locations like Singapore but combined with the benefits of proximity, knowledge and experience of the key markets of Europe and the US. **Channel Island broadband speed ranking worldwide (2017)** 1st Singapore ranks 1 of 90 countries worldwide 10th Jersey 54th Guernsey

RANK	COUNTRY	AVE. SPEED (MBPS)	5GB DOWNLOAD TIME	± 2017 (RANK)	± 2017 (SPEED)
1	Singapore	60.39	00h 11m	-	5.26
2	Sweden	46.00	00h 14m	-	5.84
3	Denmark	43.99	00h 15m	1	10.45
4	Norway	40.12	00h 17m	3	10.99
5	Romania	38.60	00h 17m	13	17.27
6	Belgium	36.71	00h 18m	2	9.34
7	Netherlands	35.95	00h 18m	-2	2.43
8	Luxembourg	35.14	00h 19m	25	19.62
9	Hungary	34.01	00h 20m	6	10.85
10	Jersey	30.90	00h 22m	4	7.6
11	Switzerland	29.92	00h 22m	-1	2.99
12	Japan	28.94	00h 23m	-	4.47
13	Latvia	28.63	00h 23m	-7	-1.73
14	Taiwan	28.09	00h 24m	-11	-6.31
15	Estonia	27.91	00h 24m	-2	3.8

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New content services

5G will deliver a meaningful and efficient broadcast service. Generic broadcasting is fading in favour of more personalised and targeted services. For instance, news and information can be broadcast for a specific group of people at local, regional or national level.

A single 5G Network not owned or operated by the existing operators, will offer opportunities to attract new entrants to the islands broadcast market by encouraging competition at the service level, rather than at the network level.

[redacted]

Local broadcast content - the network can be configured to encourage local businesses to create local broadcast media streams for local sport, entertainment and events. E.g. St James, Performing Arts Centre, GFA, Rugby Clubs etc. These groups could monetise their content to local consumers for small subscription fees (e.g. £1/m).

Healthcare

While fewer studies have focused on Healthcare 5G use cases, it is still considered that technology driven innovation will have significant impact on both health practitioners and patients. Analysts predict a world where healthcare is not just about treating illness, but also preventing illness and proactively enhancing wellbeing and quality of life. As new business models emerge, clear regulation will be required. In particular, data privacy will need to be considered, as wearable technologies increasingly collect personal health data in non-clinical settings.

Taking EU figures, the cost of healthcare is projected to rise due to an aging population in the next 30 years, by which time roughly 1 in every 8 people will be more than 80 years old. If we consider a future where there is widespread cultural acceptance of technology driven intervention and a supportive regulatory landscape, then change is likely and healthcare moves beyond just treating illness to proactively encouraging prevention, wellbeing and quality of life via remote and technology driven opportunities.

EU working groups have identified a number of key areas that will drive change:

- Big Data – the availability of large amounts of data will encourage new ways of analysing health and treatment regimes, also providing new opportunities for the pharmaceutical industry in understanding the efficacy and applicability of drugs.
- Wide area sensing – extending the use of medical sensors beyond the hospital and into the community. Raises potential issues about ownership, use, sharing and storage of data.
- Legislation – there is a strong need for transparent regulation of health data. The rights of patients, health professionals, insurers and researchers may influence the potential for innovation.
- Private versus public – innovation in the private healthcare sector may overtake public providers and become the de facto new standard.

Increased reliance on technology coupled with an ageing population could see the emergence of multiple service providers using technology to deliver care. Insurers are already rewarding customers who stay fit and governments may wish to do something

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similar. The ability to diagnose and cure remotely will significantly increase the dependency on technology, where failure could be hugely disruptive.

It is recommended that the Islands consider owning the network provision of Health Care Services via 5G when the technology has matured. This could be provided via a 5G community services layer owned and run by the local Government (see diagram at the end).

Automotive.

Automotive is by far the most alluded-to sector in 5G use case studies, and while the automotive industry may not immediately feel relevant to the Channel Islands economy, many of the examples and opportunities identified will have a relevance to both consumers and other relatable industry verticals.

Studies have identified several potential disruptors, all relevant to the islands, where 5G can play a role supporting potential solutions:

- The availability of fuel - as the price and availability of fuel inevitably becomes more of a challenge, so technology will increasingly be looked to provide solutions.
- Autonomous Driving - relates to a changing perception and experience of cars as they become less objects that are driven, to more as a means of moving between two locations, freeing up time for other tasks such as work, leisure, etc.
- The sharing economy - could see ownership of cars decrease as the growth of 'Mobility as a Service' increases.
- Proliferation of e-mobility - better communication services will enable people to reduce their physical mobility needs.
- IT innovation: more cloud and on-board services maintain the adoption of new innovations and services in cars. This could be disruptive; customer interest might shift towards services rather than the car.

Transport

There are in excess of 80,000 vehicles registered in Guernsey, 72% of which are private cars. A modern "smart" vehicle will likely have in excess of 30 sensors, meaning there will be a very large number of licence exempt radio devices in use in the island and a huge amount of potentially useable data. For example, Guernsey is seeking alternative ways to generate revenues from vehicle usage e.g. pay per mile. A connected car via a 5G network could give real-time mileage usage with some form of charging mechanism.

Where there is a supportive government and a motivated industry, new business models will emerge developing applications taking advantage of the availability of these vast amounts of data to transform the travel experience and change users' behaviours.

Transport systems tend to evolve relatively quickly and early research suggests that a new balance of public and private sectors could see vehicle sharing models starting to replace vehicle ownership models, reducing traffic in urban areas. The availability of ubiquitous transport data can also support the accelerated introduction of autonomous vehicles.

Amongst the key areas driving new models in transport are:

- Increased urbanisation - while not such an issue in the Islands, similar challenges do exist in the more congested urban areas.

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- Technology and connectivity - both smart vehicles and smart roads / cities will be contributing factors.
- Communities - drive for sustainable behaviours, society moving towards more walking, cycling etc. along with new models of ownership, e.g. sharing.
- Climate change - transport is a major contributor to pollution. Technical innovations and alternative business models along with new government policies will all help bring about sustainable changes in energy and resource use.

Energy/Utilities

Studies predict that utilities will account for roughly two-thirds of wirelessly connected smart devices by 2020. Global investment in smart grid technologies is expected to hit $400 billion in 2020.

Appropriate regulation and government support will encourage investment and competition, enabling a single 5G network to support the trust, control and liability issues, helping the islands to manage future energy demands. A high performing network and investment from competing suppliers in technology and solutions will enable fast, reliable distribution and monitoring of energy consumption and capacity.

Current research has identified the following key areas driving future energy policies:

- Smart meters – almost all homes should have an installed smart meter by 2020
- Hyper-local generation – the emergence of more local energy generation and "micro-grids" based on renewable sources.
- Regulatory changes – for example, balancing forms of supply (e.g. renewables vs fossil fuels) and target setting to manage security of resources.

Smart Cities

St Helier and St Peter Port can be considered as the only areas that can be categorised as "cities" in the Channel Islands (although they fall a long way short of the EU definition of a population over 100,000). Like other cities however, St Peter Port and St Helier do contain a large number of people and businesses that are relatively well connected by existing fixed and wireless solutions. The key benefits to be realised by 5G will relate to enhanced communication and information access for policymakers, citizens, businesses and others.

Key benefits foreseen in Smart Cities:

- Improvements to transport infrastructure and access to real-time information through enhanced wireless communications will help to reduce congestion, bringing about faster journey times and leading to lower CO_2 emissions.
- Enhanced access to information for administrators – information from new wireless sensors located throughout Smart Cities will give policymakers access to a wealth of real-time information. By employing innovative data analytics, better insight into how the city operates can be obtained allowing strategies to manage detrimental effects to be developed (congested areas, accident black-spots, crime hot-spots, high pollution areas, etc.).

Non-urban Environments

Following the EU definition, the majority of the Channel Islands can be considered as non-urban. This more rural type of environment has tended to lag behind the urban environment in terms of access to cutting edge broadband capability and the digital

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technologies enabled by it. 5G has the potential to make these types of services more economically feasible.

Deployment of a single 5G network, pooling infrastructure, resources and sharing spectrum could significantly reduce the cost required to allow government to provide public safety, utilities and transport systems to areas previously left poorly served by these types of services. The virtualisation capabilities in 5G (e.g. network slicing) would allow these services to share a common infrastructure with other commercial services which would otherwise not be viable [redacted]

The increased capacity and performance of 5G can be a key enabler for more digital businesses to locate to non-urban areas.

By building a single 5G network sharing infrastructure not only reduces cost, increasing the economic feasibility of the network, it also avoids duplication (or triplication) of infrastructure, reducing the environmental impact of new base stations and the associated civil works.

Smart Homes

Of the almost 27,000 domestic properties in Guernsey for example, more than 86% are connected to some form of broadband, the majority of fixed services being legacy copper based. 5G has the potential to "fill the gaps" and connect those homes currently un-connected and transform broadband performance.

Estimates predict that by 2020 most connected Smart Homes could have as many as 200 radio equipment devices. The benefits expected from these devices can be expressed in 2 areas:

- Reduced energy consumption – considered one of the key economic benefits from 5G, the ability to monitor energy consumption in real time would drive habits that minimise usage, helping to reduce household spending on utilities such as electricity, gas and water. The ability to remotely control systems while away from home is another economic benefit. Studies recognise that most of this can already be done today, but more informative control from a wider ecosystem of applications and solutions is enabled by 5G.
- Time Saving – improved efficiency allowing people living in Smart Homes to adjust their lifestyles for the better.

Studies highlight the potential for new business models facilitated by the Smart Home – energy consumption taxes, real-time home insurance, improvements in product warranty models, etc.

Smart Homes will enable improvements in security via enhanced alarm systems, the ability to remotely control lights, door locks, etc. and better safety features with fire, water, etc. sensors linked automatically to the emergency services.

Those requiring at home medical support and assisted living will also benefit from the proliferation of remote sensors able to detect movement for example will also be better supported in a modern 5G connected smart home.

Smart Workplace

The majority of businesses in the Channel Islands (some 79%), are in the Finance sector. 5G technology has the potential to change the existing definition of the workplace. The concept of the "anywhere office" where technology solutions make working from home or

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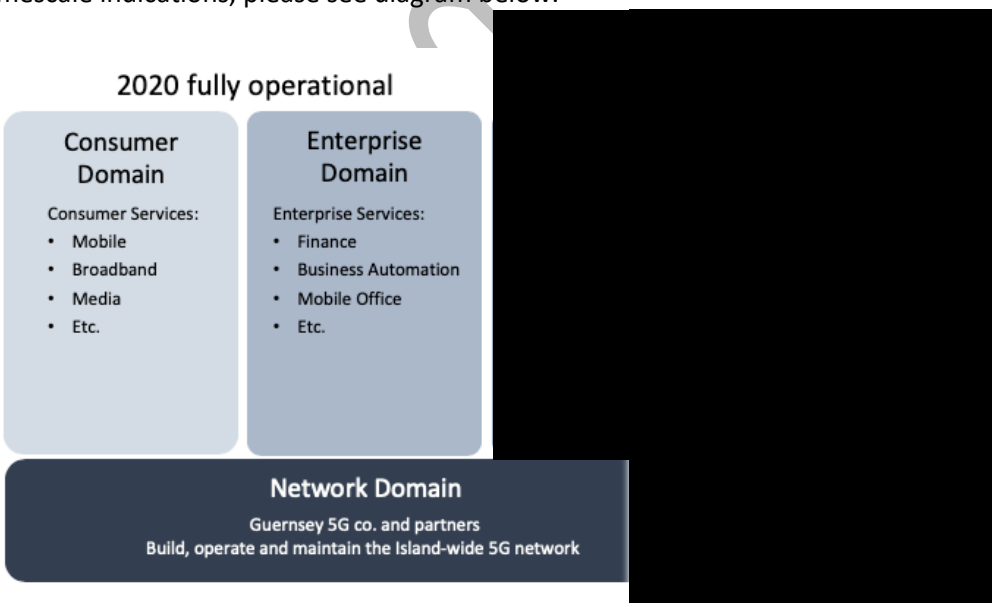
	a conveniently located hot desk a truly inclusive reality, can have a profound impact on traditional city environments. The technologies enabled by 5G to support an ageing (or disabled) population will allow people to work more flexibly and contribute in the workplace for longer, leading to happier and more productive lifestyles. All of these benefits of 5G will contribute to more efficient, cleaner and happier work environments. The true economic benefit for the Islands will depend on market structure and the development and availability of supporting economic infrastructure. [redacted]
Q2	In what timescale do respondents believe these services and benefits can be delivered.
Ans	The answer to Q1 above outlines both the short term and medium term (10 years) evolution of 5G. The standard is new and will continually evolve going forward. Some of the technologies discussed above are in their infancy, however planning, legislation and technology architectural issues are important to understand and plan for today. For timescale indications, please see diagram below. 

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Q3	Are there any potential opportunities for existing or new operators to partner with government(s) to enhance the economic value of the 5G network or to better meet the policy ambitions in either or both jurisdictions?
Ans	Telecommunications Union (ITU) gave the following overview of 5G: "At the highest level, 5G is an opportunity for policy-makers to empower citizens and businesses. 5G will play a key role in supporting governments and policy-makers in transforming their cities into smart cities, allowing citizens and communities to realize and participate in the socio-economic benefits delivered by an advanced, data-intensive, digital economy." With this in mind, the recommended objectives are: • Create a world first business model for a mobile network. [redacted] • 'Open skies' market for possible new entrants with new innovation & pricing. • Environmentally beneficial vs multiple network models. [redacted] • Address the issue of a potential digital divide [redacted] • [redacted]
Q4	Respondents are asked to consider the most appropriate means for the allocation of 5G spectrum for the Channel Islands – an auction, a comparative selection process ('beauty parade') or alternative method.
Ans	A comparative selection process is recommended.
Q5	Respondents are asked what spectrum allocation would be necessary and in what bands for an operator to offer the services and provide the benefits described in Question 1.
Ans	The initial 3GPP 5G standard "5G New Radio (NR)" supports existing mobile bands as well as new, wider 5G bands. It supports channel bandwidth sizes ranging from 5MHz to 100 MHz for bands below 6 GHz, and channel sizes from 50 MHz to 400 MHz in bands above 24 GHz. The full capabilities of 5G will only be realised through the wider channel sizes in new 5G bands. The ITU's minimum technical requirements to meet the IMT-2020 criteria – and thus the fastest speeds – specify at least 100 MHz channels per operator. They also specify support for up to 1GHz per operator in bands above 6 GHz. In summary, 5G needs spectrum within three key frequency ranges to deliver widespread coverage and to support all use cases, below 1 GHz, 1 - 6 GHz and above 6 GHz: 1. Below 1 GHz (the coverage layer) will be used to support widespread coverage across urban, suburban and rural areas and help support Internet of Things (IoT) services 2. 1 to 6 GHz (the coverage and capacity layer) provides a mixture of coverage and capacity benefits. This "prime" range includes spectrum within the 3.3-3.8 GHz range which is expected to form the basis of many initial 5G services

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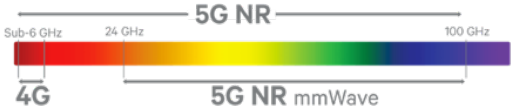
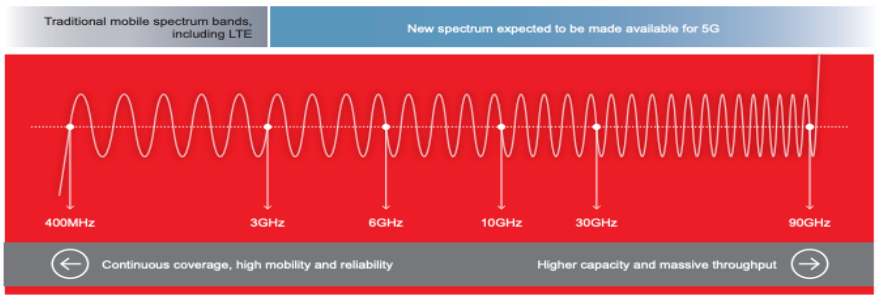
	3. Above 6 GHz (the super data layer) is needed to meet the ultra-high broadband speeds envisioned for 5G. Currently, the 26 GHz and/or 28 GHz bands have seen the most international support in this range. (A key focus at the ITU World Radiocommunication Conference in 2019 (WRC-19) will be on establishing international agreement on 5G bands above 24 GHz)  The wholesale Netco requires access to 100 MHz of contiguous spectrum in the prime 5G bands, e.g. 3.5 GHz and at least 1 GHz of contiguous spectrum in the millimeter wave bands, e.g. above 24 GHz. The prime 5G mid-bands (e.g. 3.5 GHz) and millimeter wave bands (e.g. 26 GHz and 28 GHz) will suit dense 5G small cell networks in urban hotspots where additional capacity is vital. However, these frequency bands can also suit macro cells for wider area coverage – including fixed wireless access – using massive MIMO and beamforming. These technological advancements mean that the 3.5 GHz band can provide similar coverage, and use the same cell sites - as the current 2600 and 1800 MHz mobile bands. Spectrum below 1GHz will be needed to extend high speed 5G mobile broadband coverage across urban, suburban and rural areas and to help support IoT services. 5G services will fail to reach beyond urban centres and deep inside buildings without this spectrum. A portion of UHF television spectrum should be made available for this purpose through the second digital dividend. The European Commission supports the use of the 700 MHz band for 5G services. *Sources: ITU report 'Minimum requirements related to technical performance for IMT-2020 radio interface'* *'European Commission stakes out 700 MHz band for 5G' – Telecom TV (2016)*
Q6	Would this demand for spectrum vary depending on whether there were single or multiple networks developed in future (for example, at the end of any exclusivity period), or as technologies develop in future?
Ans	Yes, in a multiple network scenario spectrum would be used inefficiently (as it is today) – however there will be an increasing demand for more spectrum due to increasing connectivity demands on the technology (see appendix for further detail) therefore, spectrum efficiency will become an important consideration given the physical limitation of the available frequencies. Lack of available spectrum will put limitations on the future performance of a 5G network. 

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Q7	Does this Draft Statement of Intent support and align with the policies of the States of Jersey and Guernsey? If not, what alternative approach could CICRA take to implement government policies?
Ans	Broadly yes, although the two Islands have different views on deployment architecture, timing and technology capabilities. Jersey is heavily influenced by its interest in its local fibre investment. Jersey may therefore be driven to protect its investment in fibre as 5G has the potential to disrupt that investment (to the home). Guernsey appears agnostic and its requirements are clearly stated in its Telecommunications Strategy. This could create complications when trying to align both Islands to one strategy.
Q8	Respondents are asked to comment on the issue spectrum initially only to one operator in Jersey and one operator in Guernsey, which may be the same operator.
Ans	CICRA could consider awarding spectrum to a single independent wholesale only mobile network operator for the reasons provided in the Q6 response.
Q9	What period of exclusivity would be sufficient to ensure a fair return on investment for a single operator before the remaining spectrum became available for allocation?
Ans	Please see answer Q6 – a new mobile network model is recommended
Q10	Respondents are asked to consider the types of conditions which would be necessary to encourage the development of retail competition during the rollout of 5G services.
Ans	This submission is recommending CICRA, and local Governments facilitate the creation of a single mobile wholesale only service provider to local operators. With a flat open wholesale network, there are no barriers for new brands and new types of services to enter the market (subject to regulatory approval). [redacted] [redacted]
Q11	Respondents are asked to consider the types of conditions which would be necessary to protect consumers and ensuring the most efficient use of spectrum as a scarce resource.
Ans	A single wholesale Netco model as discussed is more efficient than multiple network models where each operator holds spare capacity 'just in case', or for reasons of competitive spectrum denial to new operators or competitors. The Netco can provide quarterly KPIs showing capacity usages in each of the bands, with forecasting based on usage statistics. It is not in the interest of a neutral wholesale network to withhold or use spectrum inefficiently. This can be mandated via regulation.
Q12	What are the environmental and planning considerations which CICRA should take into account when considering spectrum allocation? This may include respondent views on the number of any additional sites which may be required in each Island.
Ans	A single network will reduce three networks to one over which many operators can operate. However more micro sites will be required.

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	Planning, site availability - access to existing base stations sites across the islands will allow a much faster rollout for 5G. While new antennae will be required, the use of existing physical infrastructure – tower, poles, power, etc. will ensure a much faster deployment. Additional new sites will also be needed, and support with the acquisition and planning process to advance new site development needs to be understood before the planning process starts. See planning comments on page 5. **Environmental -** one network requires less power per site and less standby power per site (batteries). Each transmission site uses between 1.5 – 3Kwh, there are 274 transmission sites in the Islands. There is potential to significantly reduce power consumption in a shared network environment. **Radio transmission health concerns -** whilst there is no scientific evidence linking a reduction in human health to increasing use of radio transmission at high frequencies, it would be prudent to limit transmission as much as feasibly possible. Merging three networks into one would be a pragmatic approach to address these concerns.
Q13	What are the health and safety consideration which CICRA should take into account when considering spectrum allocation? This may include respondent views on reassurance to the public.
Ans	It is an important consideration. There is much misinformation online leading to both public and media confusion, leading to mistrust from citizens. Clear media statements are required, and operators should be audited to ensure safe power outputs are maintained (as is currently the case). One network operator can help inform local opinion with one simple message on the topic.
Q14	Are there any other considerations which CICRA should take into account in order to maximize the economic benefits which can be achieved through the allocation of this spectrum? Are their additional ways in which economic and social benefits could be maximized, perhaps through partnerships with government to stimulate additional growth or bring down costs for consumers?
Ans	Already addressed.

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Appendix 1.

What is 5G…?

Through gigabit data speeds and significantly improved performance and reliability, 5G promises to transform end user experience, enabling new applications and services. These high speeds and low latency will deliver benefits in 3 main categories defined by the ITU:

- Enhanced Mobile Broadband (eMBB) – significantly enhanced indoor and outdoor broadband capability enabling, e.g. improved enterprise collaboration, augmented and virtual reality. Expected to be the primary use case for 5G in its early deployments. eMBB will bring high-speed mobile broadband to crowded areas, enable consumers to enjoy high-speed streaming for in-home, screen and mobile devices on demand, and will allow enterprise collaboration services to evolve. eMBB also offers a compelling last-mile solution in those areas lacking fibre connections to homes.
- Massive Machine-Type Communications (mMTC) - smart cities, smart home, smart agriculture, IoT, asset tracking, energy monitoring, remote monitoring. Driving the evolution of smart cities and IoT through the deployment of low-power sensor networks in cities and rural areas. The security and robustness of 5G will make it suitable for public safety as well as for use in mission-critical services, such as smart grids, police and security services, energy and water utilities and healthcare. Its low latency performance characteristics make it suitable for remote surgery, factory automation and the control of real-time processes.
- Ultra-Reliable and Low-Latency Communications (URLLC) - autonomous vehicles, smart grids, remote patient monitoring and eHealth, industrial automation. Encouraging the evolution of intelligent transport systems, enabling smart vehicles to communicate with each other, and creating opportunities for connected, autonomous cars and trucks.

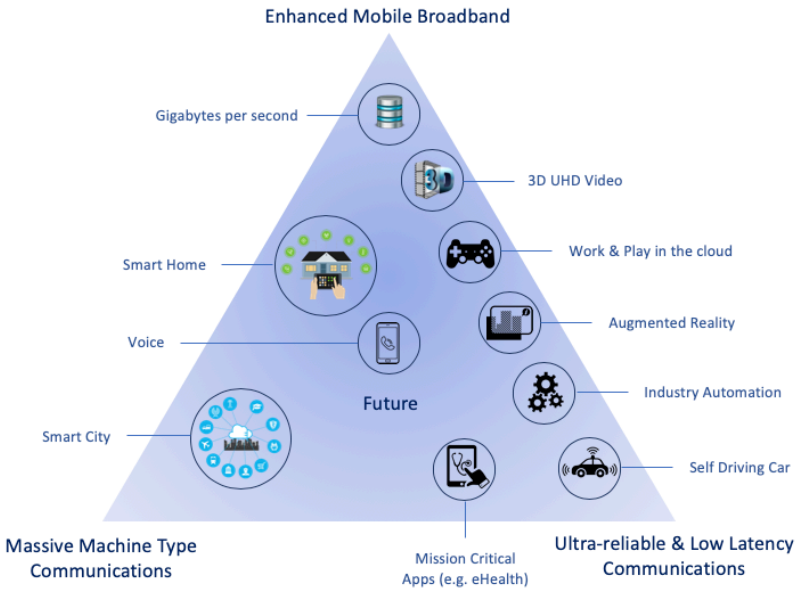

Figure 1: Communication types

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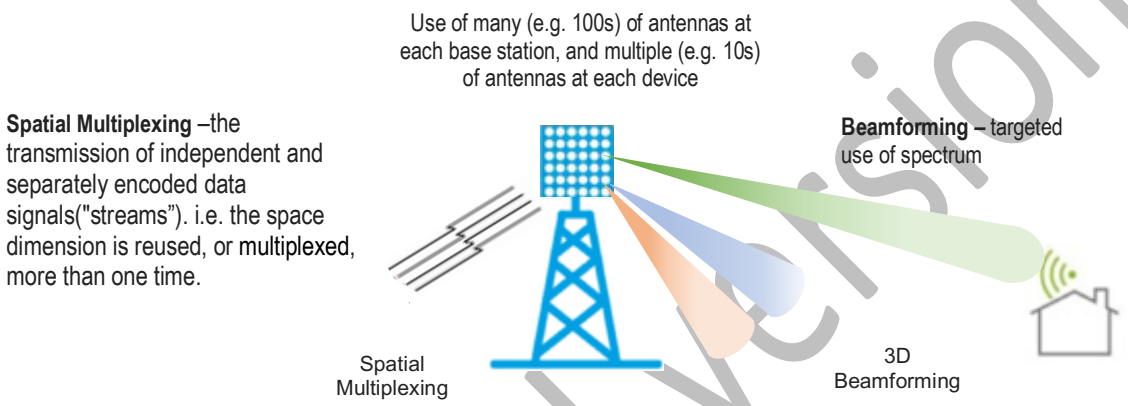
Massive MIMO

Massive MIMO (Multiple-Input Multiple-Output) technology will be a core component of super-fast 5G networks. MIMO can essentially be characterized as a wireless network that allows the transmitting and receiving of more than one data signal simultaneously over the same radio channel, typically using a separate antenna for the transmitting and receiving of each data signal.

Standard MIMO networks tend to use two or sometimes four antennas to transmit data and the same number to receive it. Massive MIMO, as the name suggests, uses a much higher number of antennas – 10s or even 100s (For low mobility use cases, designs using thousands of antenna elements are possible)

Because MIMO systems need to physically pack more antennas into a small area, they are best suited to the use of higher frequencies (and hence shorter wavelengths).



The advantage of a MIMO network is that it can significantly increase the capacity of a wireless connection without requiring more spectrum. Trials indicate a capacity improvement of as much as 50 times over a regular network.

The more antennas the transmitter/receiver is equipped with, the more possible signal paths and the better the performance in terms of data rate and link reliability and interference handling. A Massive MIMO network will deliver greater sensitivity, improving coverage and in-building penetration for devices transmitting in higher frequency bands.

Massive MIMO will also utilise beamforming technology, allowing the targeted use of spectrum, removing a potential bottleneck seen in today's networks which share a single pool of spectrum between all users in the area.

The term "Massive MIMO" has the potential to raise apprehension in planning circles, particularly due to the possibility of the sheer number of antenna elements employed and the physical size of the antenna housing unit. The picture below shows an O2 UK installation in London - the Massive MIMO antennas can be seen alongside the regular 4G network antennas.

Redacted version