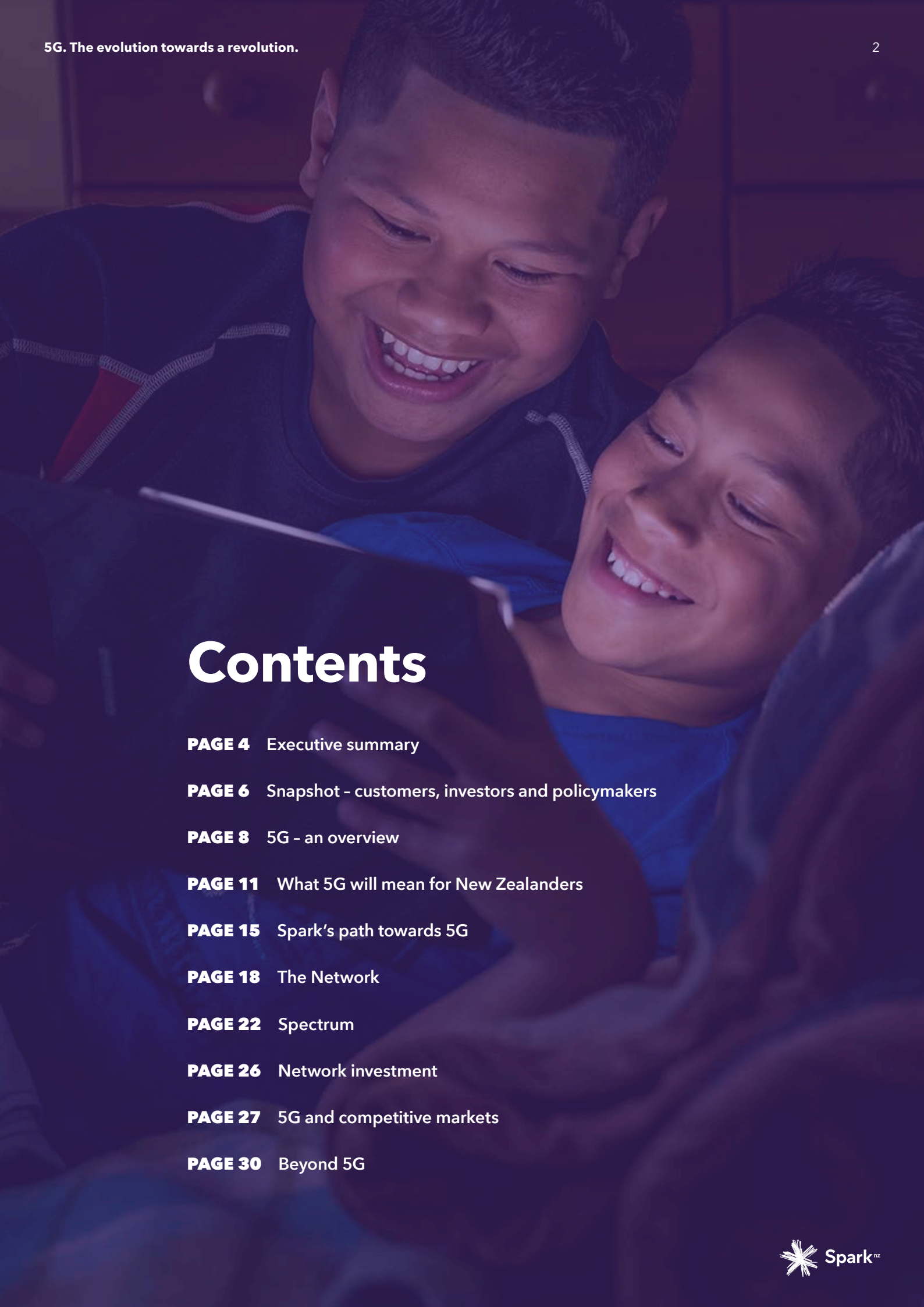
5G

The evolution towards a revolution

BRIEFING PAPER

August 2018

Spark nz



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Introduction

Spark's purpose is to help all of New Zealand win big in a digital world.

That means continuing our business transformation to improve customer experience, leading the introduction of new technology in collaboration with our business and industry partners, launching world-leading new products and services, and engaging with policymakers and community stakeholders on how we can ensure all New Zealanders benefit from and thrive in a digital economy.

We've made big strides already. In recent years, we've re-engineered our information technology systems, launched new services and partnerships, re-energised our culture, and deepened our engagement with our customers.

Spark's ongoing success requires us to meet the needs of our customers by adopting new technologies that let them communicate and do business - in New Zealand and on the global stage. 5G - the fifth generation of wireless technology - is a key element of that. Just like previous generations, 5G will be a step-change as businesses, entrepreneurs, innovators and everyday users explore and develop its potential. Its deployment will be critical to our national infrastructure.

In this paper, we provide an update of 5G developments in New Zealand and overseas, we discuss what 5G will mean for our customers and our investors, and we outline Spark's roadmap towards delivering 5G services from 2020. We also highlight the key considerations for policymakers to address if New Zealand is to achieve rapid adoption of 5G that benefits consumers, businesses and the broader economy.

5G takes us into the next technology wave. It's going to be an evolution that in time will become a revolution.

Executive Summary

Spark is leading New Zealand into a new digital era that will transform the way we communicate, the way we do business and ultimately the way we live.

The New Zealand Government has a goal to support the development of the country's fast growing digital economy and enable New Zealand to become a leading digital nation: "a nation with a thriving digital sector, where our businesses, people and government are all using digital technology to drive innovation, improve productivity, and enhance the quality of life for all New Zealanders."[1]

Spark is committed to taking a leadership role in helping New Zealand achieve this target. Our purpose is to help all of New Zealand win big in a digital world. With that purpose in mind, we design and launch innovative new digital services – such as our unbeatable unlimited mobile plan, the 1 gigabyte per day free Wi-Fi we give to our mobile customers, our recently-launched online marketplace WeDo that connects consumers and tradespeople in their local area, our Lightbox TV service and our online streaming service for Rugby World Cup 2019. Our purpose also drives our planning for and investment in world-leading digital technology and networks.

The next generation of wireless technology is known as 5G and it's now just around the corner. We will build New Zealand's best 5G network and we've already started laying the groundwork for that network so that, once 5G spectrum is made available, we are in position to build our network and launch 5G services in short order.

5G will start as an overlay of existing 4G and 4.5G networks.

Planning for our 5G network started some time ago. In 2016, Spark was the first operator in New Zealand to deploy 4.5G technology, as a pathway towards 5G. During 2018, we have accelerated that preparatory work and launched an extensive cell site deployment programme that will increase the density of our mobile network in preparation for 5G. And in March, we conducted New Zealand's first ever live 5G tests in Wellington and Auckland, achieving speeds of 9 gigabits per second (Gbps) outdoors and 18 Gbps indoors – hundreds of times faster than the typical speeds experienced by most New Zealand wireless device users today.

There is still much to be done to bring a commercial 5G network to reality in New Zealand – importantly, the Government is yet to allocate 5G spectrum. However, our 5G network planning is well advanced and global device manufacturers are gearing up to produce 5G-capable devices from 2019.

The superior performance and cost-efficiencies of 5G will encourage rapid network investment.

5G, like 4G and 3G before it, will deliver customers higher speeds, more data, and better performance, at lower incremental cost (per unit of data) than previous generations of technology could. And it will be critical in allowing Spark to continue to keep up with our customers' ever-growing demand for wireless data. Data traffic on Spark's 4G network is almost doubling every year and will start to outgrow our 4G network's sensible limits by around 2020-21. By that time, it will make much more sense for us to invest our capital in more efficient 5G wireless capacity than in further expansions of 4G capacity.

5G technology creates the opportunity for a wide variety of very different 5G services as and when demand for them arrives.

5G will also open up a world of new possibilities for New Zealanders that in time could transform our lifestyles and our economy.

[1] http://www.mbie.govt.nz/info-services/digital-economy

Rather than a single network with set functionalities, 5G is better thought of as a "network of networks", with the potential for multiple parallel networks known as "network slices" - each designed to provide very different performance characteristics - all sharing a common physical network infrastructure.

At the same time as enabling revolutionary technologies such as automated cars, virtual reality services and advanced manufacturing that rely on ultra-reliable real-time communication, 5G will also allow smart cities to connect millions of devices together to enable them to manage civic infrastructure and utilities in a more efficient and environmentally responsible way. Whereas today the very different performance characteristics of these use cases would require their own standalone networks, in the future all of them will be supported on a single shared 5G network through the use of network slices.

We expect the 5G network (covering multiple bands) will support multiple different services with widely divergent connectivity requirements. This will fundamentally change the economics of the digital business models that many industries have already identified as their future - but have yet been unable to economically realise. We expect it will allow them to push the bounds of those digital business models even further.

Because of the extendable nature of 5G, we will be able to deploy network slices delivering particular performance characteristics or services as and when commercial demand for those services warrants. In each case, service-specific equipment may be required to be deployed at different parts of the network, and in some cases network density - the number of cell sites required to provide the required coverage - may need to be increased, but these will simply be extensions to the 5G network, able to be deployed as and when there is sufficient demand for them.

While we will start by deploying a 5G network that delivers superior performance and lower incremental operating costs for our existing mobile and wireless broadband services, that same network will be readily extendable to support the next generation of digital business models and services as they arrive.

5G will initially deliver faster, better mobile and wireless broadband services, but will be capable of so much more.

Crucially, we do not expect the next generation of digital business models and services will be determined solely by telecommunications network operators. Rather, they will be conceptualised by the businesses and people who live and work in the industries and communities these new business models and services will transform. The role of Spark will be to collaborate with these businesses, ensuring the right 5G capabilities (such as 5G network slices and network densities) to support them are built to demand. We want to put the challenge out to all New Zealanders and to New Zealand businesses to start that conceptualisation work now, and to talk to us about it.

In the fourth quarter of 2018, we will launch Spark's 5G Innovation Lab in Auckland's Wynyard Quarter Innovation Precinct that will allow companies and partners to test and develop future 5G applications over a pre-commercial 5G network. We're actively looking for partners with exciting 5G use-cases who can use the Innovation Lab to refine and prove them.

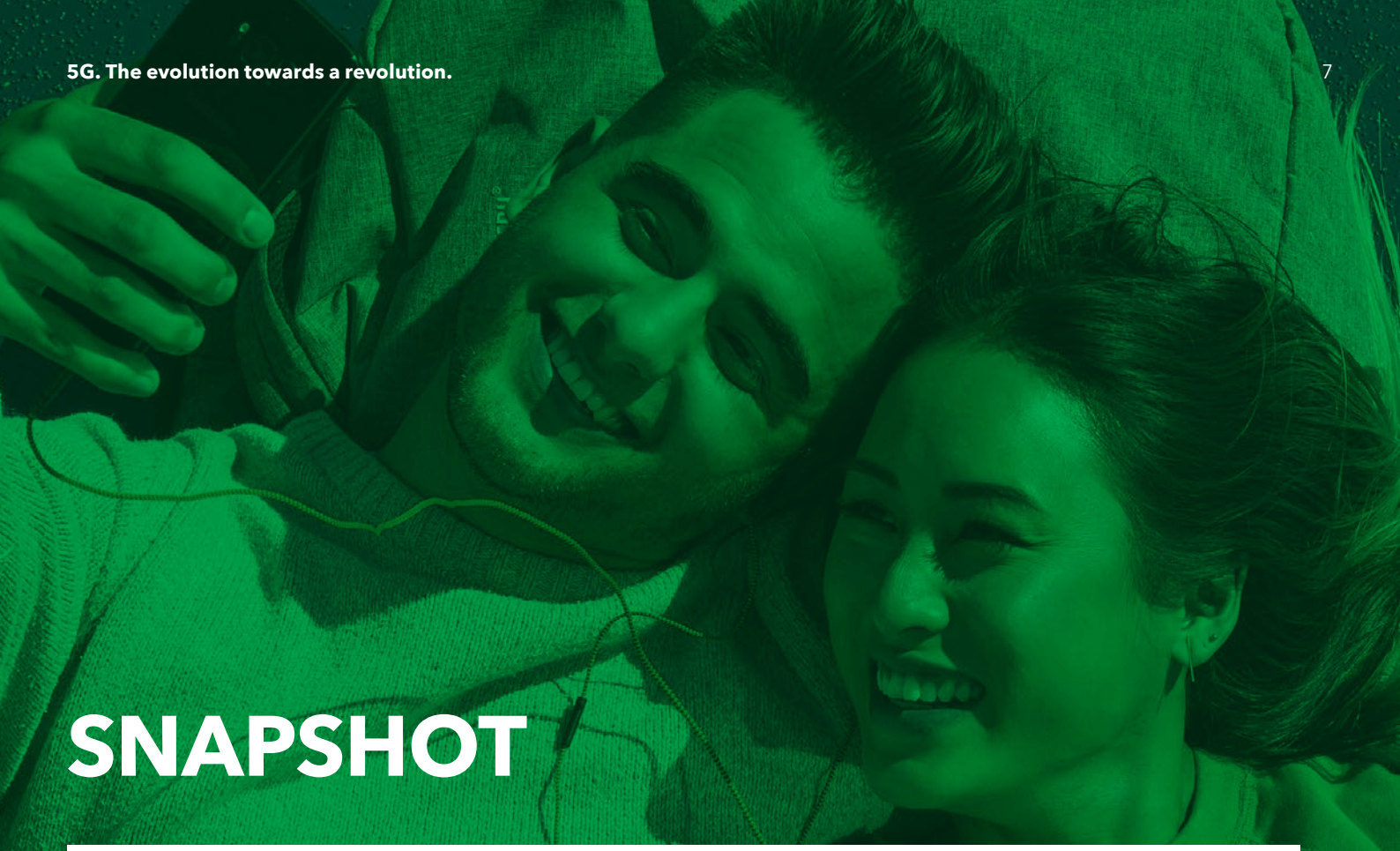
SNAPSHOT

For Spark's customers

- Spark is on track to start providing 5G services to consumers and businesses from 2020. Our technical and network planning is advancing; we have already conducted successful trials and we will launch our 5G Innovation Lab in Auckland's Wynyard Quarter Innovation Precinct in late 2018 that will allow companies to test and develop applications over a pre-commercial 5G network.
- With 5G, we will be able to offer customers much faster speeds and more data at prices similar to what they pay today – as the technology allows us to deliver better performance at a lower incremental cost per unit of data.
- Many of the services that 5G enables will involve massive growth in both the number and type of connected wireless devices and sensors. In terms of consumer devices, 5G-capable wireless broadband modems are expected to be among the first available, with production by the global manufacturers of 5G-capable smartphones increasing rapidly from 2019 onwards.
- 5G services will initially be available mostly in built-up areas because the mid- and high frequency spectrum bands that are likely to be first allocated by the Government do not have the radio signal reach to make them feasible for use across large areas of sparsely populated rural New Zealand (outside of small provincial towns). Once low frequency spectrum bands are available for 5G, we will be looking to a range of options, including network sharing, to address rapid network expansion as widely as possible.

For Spark's investors

- 5G will enable us to provide additional capacity at a lower incremental unit cost than from continuing to expand 4G capacity.
- This means that once 5G is available, we will have a strong commercial incentive to rapidly build 5G network capability as the primary means of keeping ahead of growing customer demand for more data at faster speeds.
- We expect our 5G network development to be funded within Spark's existing capital expenditure envelope (excluding spectrum and any material move towards widespread rollout of new cell sites using high frequency mmWave band spectrum), as we divert spend from 4G capacity expansion into 5G as soon as we have the available spectrum.
- Our investment profile will be moderate and within the current "normal" range for capital expenditure of between 11%-12% of revenues.
- The current competitive market model, in which multiple wireless network operators compete against one another to grow their customer bases through product and service innovation and pricing, represents a good blueprint for the way 5G can be rolled out in New Zealand. This model, if continued to be adopted by Government, will provide for more investment predictability and certainty over the coming decade.



SNAPSHOT

For policymakers

- With 5G, Spark will enable significant benefits for consumers and businesses, which in turn will deliver wider benefits to New Zealand, enabling the country to maximise opportunities from global technology advances.
- A competitive market model involving existing wireless network operators and potentially new entrants is the best way to ensure New Zealand consumers and businesses benefit from 5G.
- Future services will be increasingly complex and fast changing, so it is important to ensure both policy and regulation allows for flexibility and encourages the rapid introduction and adoption of new services, for the benefit of consumers.
- 5G services are not a standalone technology or solution. As with 4G/4.5G, it will operate together with and will be deployed as an overlay of existing wireless network infrastructure. Policy settings need to support network operators having control over the evolution of their wireless networks.
- Mid frequency spectrum allocated for 5G, in what is known as the C-band, needs to be available to operators in sufficiently large blocks (of at least 80MHz, ideally 100MHz) to ensure they can build 5G networks exceeding current 4G performance. Speeds and performance that materially exceed 4G will require the use of much larger blocks (minimum of 400MHz, ideally two blocks totalling 800MHz) of high frequency mmWave band spectrum.
- The C-band and mmWave band spectrum allocation processes should be completed as soon as possible, to ensure 5G services can be delivered in time for the 2020-21 America's Cup in Auckland as an international showcase opportunity.
- Regardless of the operator, low frequency spectrum will be required to deliver 5G services on a pervasive basis into rural areas (outside of small provincial towns). The current work to define 600MHz spectrum as a band applicable to cellular networks should continue at pace.
- Innovative transport solutions will become increasingly important as there are more cell site locations requiring high-speed connections to the network core. 5G requires new solutions for transport, using a mix of microwave- and fibre-based technologies. Regulatory support may be required to ensure transport links controlled by third parties are available on fair commercial terms to wireless network operators.

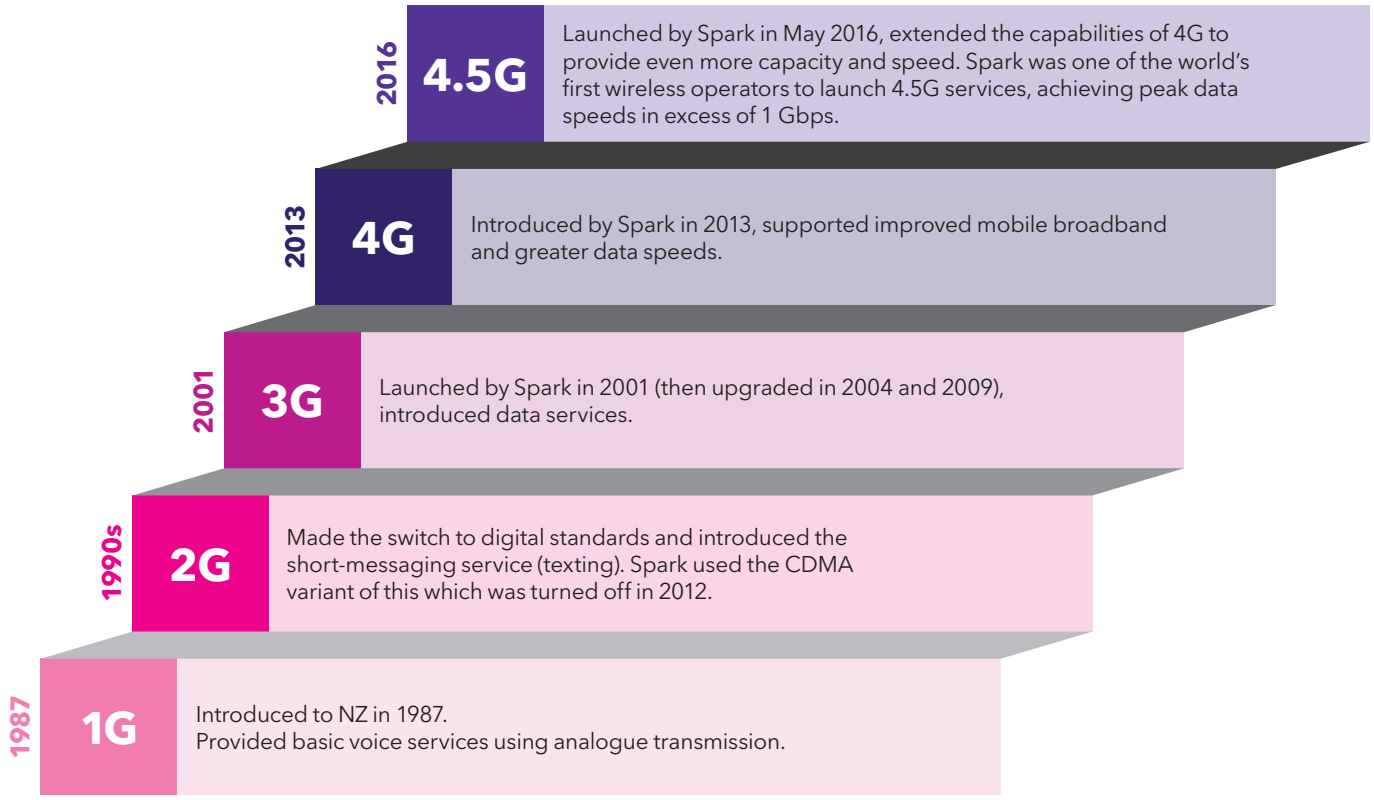
5G – an overview

5G is the fifth generation of wireless communications technology and it's starting to be rolled out around the world. It's the key to a worldwide wireless-centric technology revolution that will develop over the coming decade.

5G will enable:

- **Greater speed and capacity** – the ability to move more data, faster without a corresponding increase in costs – as the technology allows wireless network operators to deliver better performance at a lower incremental cost per unit of data.
    - Typical speed improvements of up to 10 times faster than today's experience, and peak speed improvement from close to 1 Gbps possible in a 4.5G network to 10 Gbps.
    - 10 Gbps speeds are only possible using high frequencies (i.e. mmWave band) with large bandwidths of up to 800MHz or more; when using mid frequencies (i.e. C-band) peak speeds are typically 1-2 Gbps.
    - By comparison, the fastest speeds available as of today for retail fixed broadband services via the current specifications of the ultrafast broadband (UFB) fibre network is 1 Gbps.
- **Lower latency** – less delay/greater responsiveness enabling real-time services to be delivered.
    - Latency improvements to 10 milliseconds (ms) and potentially down to 1ms from a typical 50ms today. This allows extreme network responsiveness and will eventually enable mass uptake of augmented reality (AR) and virtual reality (VR), as well as support mission-critical applications for industry. Latency is the delay that occurs when transmitting digital data – anything less than 10ms is generally undetectable to the human eye.
- **The ability to connect many devices at once** – sensors and smart devices that comprise the Internet of Things (IoT).
    - Even today's 4G networks are limited in the number of devices they can connect to simultaneously, because these networks were designed to support population densities. But we know that in the future connected "things" – devices ranging from fridges to streetlights to farm gates – will far outnumber connected people, so 5G technology has been designed to support connected device densities of up to 1 million devices per square kilometre.
- **Network slicing** – tailoring the network for specific uses.
    - This is, perhaps, the most transformative feature of 5G technology: the ability to tailor the network in accordance to the performance requirements of a service by virtualising functions and moving them closer to the customer. The performance requirements of, say, a connected autonomous vehicle (ultra-reliable real-time connectivity 24/7) are very different to those of a smart parking sensor network (low power, non-real time connectivity of thousands of similar devices that will use very small amounts of network capacity infrequently and at random times). In the early stages of 5G, network slicing will be enabled by virtualising key network elements, a journey Spark has already started. But as it develops, the network functions themselves will be virtualised and located in the right place within the network for the performance demands of the customer's service.
- **Edge Computing** – Taking more of the network processing functions to the 'edges' of the network.
    - This ensures network functions get the bandwidth and low latency required for key 5G services, by moving these functions closer to the cell sites supporting customer devices. But it requires new network configurations including more high-quality fibre connections to these edge functions.

Each generation of wireless technology has seen major advances over the previous iteration



5G will take us from a world of connecting people to each other and to the internet, to a world of connecting almost anything.

There are several technology realities that will influence the rollout of 5G. These include:

- As with any new generation of technology, 5G will initially be delivered as an overlay of existing network infrastructure alongside 3G, 4G and 4.5G services – not as a distinct, standalone network. This will enable 5G to be deployed on a geographic basis as and where traffic demand requires it, with customers having consistent 4G coverage where 5G coverage does not yet exist.
- The two spectrum bands that are likely to be initially allocated for 5G are the mid frequency C-band and the high frequency mmWave band.
- Spark's testing of C-band spectrum shows it has similar signal propagation characteristics (in terms of reach, penetration, etc) as the 1800MHz spectrum used for 4G. For this reason, 5G services using C-band spectrum initially won't require a large number of new standalone urban cell sites because much of the cell site densification required is already being undertaken (or will be in our plans) as part of network capacity expansion over the next few years.
- Although 5G services using mmWave band spectrum (which enables extremely fast data speeds over short distances) will require new infrastructure in dense traffic hotspots, these will be "micro-sites" not too much larger than what are used today for commercial Wi-Fi services. Most likely, these micro-sites will be located in a hub and spoke configuration around a macro-site that uses C-band spectrum.
- C-band and mmWave band are not suitable for pervasive coverage across rural New Zealand (beyond small provincial towns), because neither band has the radio signal reach to cover large, sparsely populated areas. Low-frequency spectrum bands (below 1000MHz) are needed to provide widespread rural coverage – as occurs today with Spark's 4G (700MHz band) and 3G (850MHz band) services. For this reason, Spark has submitted to the Government that 600MHz band spectrum be made available for 5G (for more details, see section on Spectrum).

A growing number of markets around the world are pushing ahead with 5G network deployment.

The USA, Britain and South Korea are targeting commercial deployment of 5G in 2019, while Canada, China, France, Germany, Japan and Russia are aiming for 2020. In the USA, AT&T is expected to be the first company with a mobile-oriented 5G network later in 2018, although it is not clear what handsets will be able to use the network immediately.

On average, in most countries, consumers who are aware of 5G see themselves using it within 30 months of its launch. Based on consumer awareness and interest, China and the United States might lead 5G consumer adoption.

Surveys show overseas customer expectations for 5G services are that most will go mainstream within three to four years of 5G launch. The leading initial requirements from consumers for 5G are better performance, coverage and pricing.

The global timeline	
2012	Initial research into 5G
2016	Initial pre-standards testing The first modem chip is released
2017	3GPP 5G Pre-Release standard for the 5G radio network is finalised
2018	3GPP Release 15 – 5G standards finalised 5G service demonstrations including at the PyeongChang Winter Olympics Early networks are launched in Qatar and Finland. These are fixed wireless, not mobile, networks using 5G over C-band The global standard for the 5G core is finalised Verizon, in the USA, has announced the launch of a 5G fixed wireless service using mmWave in four cities late in the year
2019	Qualcomm expected to build 5G Snap Dragon chip set for mmWave modem 5G-capable handsets are expected to be available Some early mobile-oriented 5G networks expected to be launched: AT&T, Verizon and T-Mobile in the USA all expect to have networks for 5G smartphones available World Radiocommunication Conference 2019 (WRC19) to standardise the global use of mmWave frequencies ITU to approve IMT-2020 standards (defining the requirements of 5G systems as they relate to network operation, software virtualisation and fixed-mobile convergence).
2020	5G networks expected to be launched in several more countries
2025	5G networks expected to be mainstream

What 5G will mean for New Zealanders

5G will bring fibre-like speeds to mobile, allowing Spark to deliver wireless performance that's better, faster and with the capacity to meet projected demand.

It will allow millions of machines to communicate with each other, and eventually it will allow complex procedures to be performed remotely.

Applications that are already occurring in New Zealand with 4G and 4.5G will be "supercharged" by the superior performance, greater reliability and lower incremental operating costs of 5G, as they become commercially feasible and used more extensively, and overcome the barriers of adoption that currently exist due to network performance constraints.

Features enabled by 5G that are expected to prove attractive to consumers include the prospect of "always on" connectivity (negating the need to log on to Wi-Fi hotspots), faster downloading of content, better-quality video calls and instant access to cloud services and business productivity tools wherever there is mobile coverage.

Key applications are expected to include:

Enhanced mobile broadband (eMBB): to meet growing consumer demand for higher-definition (e.g. 4K) video, information and social media services, such as

- Wireless broadband that delivers fibre-like broadband performance to homes and business
- Mobile services that deliver unlimited data plans and fibre-like speeds to mobile devices
- Richer media content, as 4K video becomes commonplace (and the expectation of 8K being around the corner).

Enhanced Machine Type Communications (eMTC): to support connections and communication between tens of millions of connected devices to enable digital services that can help New Zealand industries and homes become more efficient, such as

- Smart city services - smart lighting and smart energy, water and wastewater network management services
- Smart home services - connected appliances, smart home security services, and remote control and operation services
- Real-time freight tracking and logistics management services
- Stock, pasture, water, effluent and environmental management services
- Wearables and tracking of children or elderly
- Health and safety monitoring and management services

Ultra-reliable and low-latency communications (URLLC): Supporting near-instantaneous communications between connected devices to support complex and integrated multi-user networks and services, such as

- VR and AR industrial and entertainment services
- Remote operation of health, educational and industrial equipment
- Autonomous vehicles and intelligent transport systems, for example in high-risk zones like airports or for urban transport routes
- Mission-critical applications, such as remote surgery

One of the early applications of 5G for New Zealanders is likely to be an expanded range of wireless broadband products. Although wireless broadband already provides a valuable alternative to fixed broadband delivered via fibre cable or copper wire, the limitations of 4G mean it is best suited for homes and businesses with modest internet usage. For instance, Spark wireless broadband is currently offered with a maximum monthly data plan of 120 GB for most customers, with 240 GB plans only offered in selected areas where there is greater network capacity. The improved capacity and performance characteristics of 5G should encourage more innovation of wireless broadband services – for example, new pricing models (such as pay-as-you-go) and new solutions for customers with special use cases, such as boats on the move, or taking the broadband modem to a holiday home.

But as we have seen with previous generations of wireless technology, 5G will be just the starting point of change for consumers.

Businesses, entrepreneurs and technology partners will develop new applications that leverage the new network capabilities and create services that are compelling for users.

Although many applications for 5G are known today, previous wireless technology step changes have shown that other applications are likely to emerge that we haven't imagined yet. For instance, when Spark launched its 4G network in 2013, services such as wireless home broadband and unlimited mobile plans were not on our immediate roadmap, but both have since become significant new products for our customers – driven by the adoption of media entertainment services like Netflix, Lightbox and Spotify and the mass uptake of smartphones.

A key learning from the 4G experience is there needs to be sufficient flexibility and dynamism in the New Zealand market structure to enable wireless network operators to innovate and invest in new 5G-enabled services as opportunities emerge. Then, as customers, industry and innovators learn more about 5G and its possibilities, service innovation will hit the fast track.

We can expect to see the remote monitoring and adjusting of medical devices and implants, smart, dynamic management of urban transport networks that improve traffic flow and reduce the investment in building more new roads, and a wide range of VR or AR applications that will enhance the viewing experience for major sports or entertainment events such as a rugby test match or a music concert, or for a virtual guided tour of a new building from the construction site.

Longer-term services include smart-metering and smart-grid applications for the energy sector, immersive gaming, better fleet management, and dynamic track-and-trace services for the logistics

VIGILAIR

VigilAir is the brainchild of ASG Technologies Ltd, a subsidiary of TPT Group Holdings (NZ) Limited, an innovative NZ Company and a technology partner of Spark. The VigilAir SaaS product interfaces with customer electronic security systems allowing drones to respond to security events – the security guard of the future, providing a faster, safer and more cost-effective response. An important part of the system is the artificial intelligence video analytics that can be 'taught' to identify objects, behaviours and events. Conducting analytics from a moving airborne device is challenging, but can be enabled by a high-quality, high-definition video stream that provides a higher level of detail to the analytics engine. The bandwidth and low-latency of 5G will allow for the development of new VigilAir based capabilities, that will increase the opportunity to deploy the system across industries and countries.

OHMIO

Ohmio is a NZ-based manufacturer and developer of autonomous vehicles. Ohmio has been developing autonomous vehicles since 2015, with the first four-seater concept vehicles, the Ohmio HOP, being launched in Christchurch in September 2017. Ohmio is due to release its first commercial 20-person vehicle, the Ohmio LIFT, in 2018. Ohmio's autonomous vehicle platform relies on multiple modalities for sensing and communication – this is so the limitations of one modality of sensor or communication medium can be mitigated through the presence of other sensors. Ohmio's partnership with Spark allows Ohmio to integrate 5G communication into its vehicle and infrastructure with the benefits of higher throughput. As the first autonomous vehicle in the world to operate using 5G, Ohmio intends to stay ahead of competitors in a highly competitive space.

industry. Technicians in one country will be able to operate systems in another, offering global business opportunities for New Zealand companies, for example, dairy processing workers in New Zealand operating factory equipment in another country.

New Zealand lags behind its peers in planning for smart cities. Improving this will require integrated planning by central and local governments as well as the telecommunications industry. Some potential services, such as driverless cars, will require significant developments in devices (in this case cars), related infrastructure (road system technology) and legislation, as well as the upgrades to the wireless networks.

5G's ability to serve very different use-cases over a common physical infrastructure is arguably its defining characteristic.

Despite these services having widely divergent network performance requirements, each can be served over a common extendable 5G network. In each case, service-specific equipment may be required to be deployed at different parts of the network, and in some cases network density - the number of cell-sites required to provide the required coverage - may need to be increased. But these will simply be extensions to the network, able to be deployed as and when there is sufficient demand.

Initially, the 5G network we deploy will be designed to deliver improved mobile and wireless broadband services to our customers – more mobile data faster and at lower incremental operating cost per gigabyte. But as our 5G network grows, and as customers, application designers, businesses, and sectors of our economy become aware of the potential capabilities of 5G, we will extend that network through the addition of network slices designed to deliver more sophisticated performance characteristics.

In this paper we set out some possible ideas for what those characteristics might look like, and what digital services and new digital business models they might support. But we know that in practice, it will be other participants in the ecosystem who define the exact nature of many of the services to be delivered over Spark's 5G network. For instance, the transport industry will design the new digital services that dictate what a network slice for vehicles should look like. And the same will be true of every other sector of our economy that 5G has the potential to transform. We are excited by the possibilities, and we are designing our 5G network so it will be ready to support those sectors, business models and digital services, when they arrive.

5G will increasingly be about devices beyond the familiar smartphones.

The extra speed and capacity of 5G will enhance users' experience with smartphones, but this will be a "faster in more places" evolution rather than some fundamental change. Many of the wider benefits of 5G for customers will show up only when new kinds of devices are enabled with 5G end-to-end capabilities.

To a large extent, the mainstream consumer take-up of 5G in New Zealand will be influenced by consumers upgrading their wireless devices (smartphones, etc) to the latest 5G-capable models. For smartphones, we expect that devices will be available with 5G C-band support from early 2019. Whether these will be suitable for the New Zealand market is still unclear because the devices need to have a range of bands supported within them that align with the range of bands in Spark's network. For example, the United States' use of the 700MHz band is quite different to New Zealand, so a US-market handset may not work here. Typically, the second iteration of any new device offers a wider range of band support, so by 2020 there is a good prospect that compatible handsets can be sourced for the NZ market.

Although the device replacement cycle for most customers is typically every three years or so, our experience with the transition from 3G to 4G was that a significant number of customers decided to accelerate their device upgrades to take advantage of the better performance and services available via 4G. This meant that the New Zealand market adoption of 4G occurred significantly faster and at a larger scale than was initially anticipated by most in the industry. We suspect a similar scenario may play out with the transition to 5G.

Mobile broadband devices (including wireless broadband, dongles, Wi-Fi hotspots) are expected to be easier to obtain because they do not require the same range of band support. These may start to be available from late this year. Spark will be looking to provide 5G modems as part of our continued wireless broadband offering.

More advanced 5G-specific devices are likely to be several years away from mass-market availability. While prototypes exist already, there will need to be service support from major global operators for these solutions to have the volumes to become generally affordable. Spark is following these developments. Even before widespread availability of these services, Spark is developing the back-end capabilities (such as network slicing, virtualisation etc.) that will be required to support them.

SENSORIUM

Immersive live event broadcasting via 5G will be an early winner for VR. Building a long-tail of quality content will also break down one of the main barriers to mainstream consumer adoption. From New Zealand, SENSORIUM has been quietly creating and enhancing a robust production and distribution platform for live immersive experiences and comprises their own VR cameras, VR editing system and distribution application. SENSORIUM can now produce live broadcast content, and package and release delayed coverage of any live sporting event.

Their ease of production has brought the company into talks to secure the rights to produce immersive content for Mixed Martial Arts – the fastest growing sport in the world with a first proof of concept being shot in September 2018.

Spark's path to 5G

Spark has been a leader in bringing the latest wireless technologies to New Zealand since we launched the country's first cellular mobile services in 1987.

After moving to 2G technology in the early 1990s, we converted our network to all-3G in 2009 – and followed that in 2013 with the introduction of 4G services.

From mid-2016, we began enhancing our network through the progressive rollout of 4.5G – involving a combination of technologies that improve wireless speeds and capacity over conventional 4G. This was our pathway towards 5G: the 4.5G technology we deployed in our network enabled us to learn how massive bandwidth needed to be catered for not just within the Radio Access Network (RAN), but at the aggregation and Network Core levels, something we need to understand for 5G.

Each change Spark has made on its path to becoming New Zealand's wireless technology leader has pushed us to go further, but our key strategy remains the same - to have the industry's leading wireless network that delivers high-quality, reliable services to customers at the lowest operating cost, per unit of data delivered.

Like previous generations of wireless technology, 5G will transform the economics for wireless network operators, significantly reducing the operating cost per gigabyte of data transmitted – allowing Spark to deliver more data to more customers, faster and more efficiently than ever before.

In that sense, we see 5G as an evolution of our existing 4G and 4.5G services, that will initially be deployed as an overlay on the existing cell site network and then extended as demand for new services arrives. As that demand eventuates, we'll need expanded networks, denser networks and decentralised core switching and control functions – what's known as edge computing - to take full advantage of the speed, power, lower latency and capacity 5G will bring.

The most capital-intensive component of this expansion programme will be densifying our network - increasing the number of cell sites to build capacity and improve coverage. We are undertaking detailed planning to "map" expected 5G cell site densities in New Zealand and as a result of this planning (and the learnings we have taken from our 5G testing), we are forming a good understanding of how many new sites we will need for 5G, and where.

We have already begun a build programme to increase the number of cell sites – which will enable us to meet near-term capacity demand as well as lay the groundwork for network-densification required for 5G. The locations and design of these new sites have been chosen with future 5G requirements in mind, and most will cater to high traffic areas in major urban centres. As these are mostly "infill" sites to strengthen capacity between existing cell sites, most will be

Most new cell towers will be smaller and less obtrusive

While not all devices are fully 4.5G-compatible, many of the latest phones support features that can take advantage of the technology and operate between three and five-times faster than 4G. Now, 4.5G is available through 38 cell sites from Auckland to Invercargill, bringing our customers faster speeds and giving the network more capacity – providing an early glimpse of the possibilities ahead with 5G.

smaller and less obtrusive than conventional cell towers – all are being constructed as extensions to existing street lighting or utility poles.

In March 2018, we conducted New Zealand's first live 5G test site in Wellington, achieving speeds outdoors of up to 9 Gbps using high-frequency mmWave spectrum. An indoor trial in Auckland the following month, also using mmWave, achieved speeds of 18.23 Gbps. Such speeds are hundreds of times faster than the typical speeds experienced by most New Zealand wireless device users today, which tend to range in the low 10s of megabits per second. The trials have allowed us to test, in a real-world environment, the speeds, coverage and the parameters of the spectrum we'll be using for 5G.

Spark also conducted trials using mid frequency C-band spectrum to compare the coverage to what is currently achieved with the 1800MHz band spectrum Spark has in use today. 5G will deliver very similar coverage to 4G service in the 1800MHz band.

We're also starting to actively engage with customers and potential customers of future 5G services.

In the fourth quarter of 2018, we will launch Spark's 5G Innovation Lab in Auckland's Wynyard Quarter Innovation Precinct that will allow companies to test and develop future applications over a pre-commercial 5G network.

The Spark 5G Innovation Lab in Auckland's Wynyard Quarter will feature a showcase area to educate our customers on what 5G can do for their businesses. It will have an area to display some key-use cases for immersive media experience, Internet of Things, and artificial intelligence.

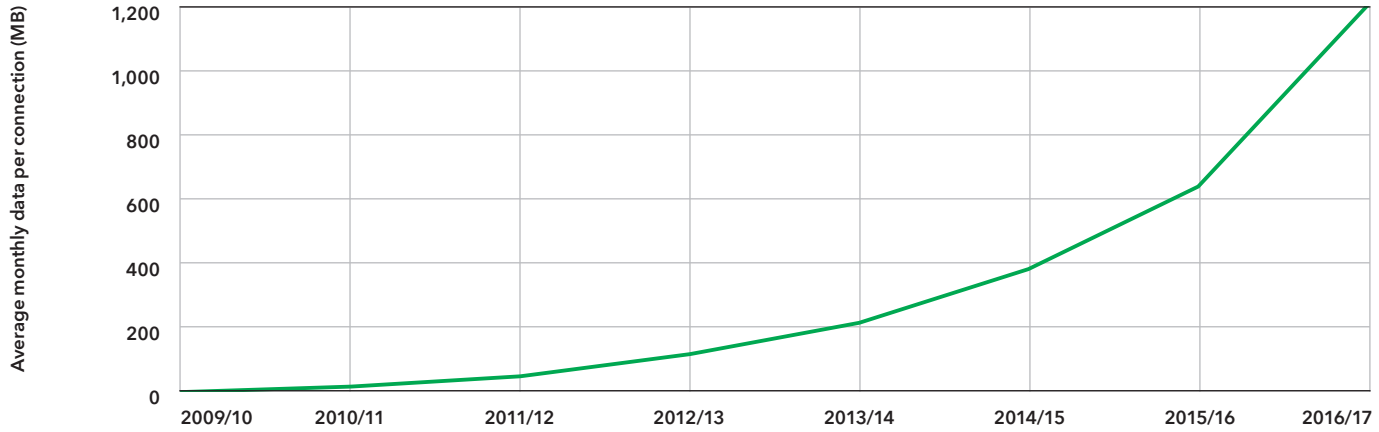
Providing early access to a pre-commercial 5G network through our global relationships with leading equipment vendors like Huawei, Cisco, and Nokia will give our local partners a competitive boost, fast-tracking these businesses' 5G developments.

The purpose-built collaboration zone will help enable Spark to collaborate with 5G Lab local partners in new applications such as autonomous vehicles, drones and virtual reality experiences.

We chose the Wynyard Quarter because the area will be the event hub when Team New Zealand defend the America's Cup, yachting's most prestigious trophy, over the summer of 2020-21. The event's international profile and strong technology focus makes it an ideal platform for New Zealand to showcase exciting innovations and new capabilities enabled by 5G.

Although our 5G lab's pre-commercial network is expected to use spectrum obtained from the Government under a temporary licence, from a technical viewpoint it could become the starting point for commercial 5G services once

Mobile data consumption continues very strong growth



Source: 2017 Annual Telecommunications Monitoring Report, NZ Commerce Commission

spectrum is available. For New Zealand to take full advantage of the America's Cup opportunity, we would want to have a 5G network operational from mid-2020. To meet this timeframe, we therefore need to have certainty in terms of spectrum allocation by late 2019.

Our customers' response to 4G reinforces the importance to Spark of leading the transition to 5G.

In the five years since 4G was launched, traffic on our wireless network has grown 25 times - it's almost doubled every year - and well over 100,000 home broadband customers are using a modem connected to the nearest 4G cell site instead of a fixed-line connection. More than 95% of handsets used on the Spark network are now smartphones and 93% of our data traffic is now delivered via 4G.

New Zealanders lives are increasingly mobile, and the way New Zealanders engage with and use technology is increasingly mobile. People want more freedom and to stay seamlessly connected wherever they are. We expect this emerging preference for wireless services to intensify in the coming years, and to reward service providers who can deliver effortless customer experiences by wireless.

We will use 5G to deliver services that reflect our customers' preference for wireless delivery and to deliver the effortless service experiences that customers value, such as:

- Traditional mobile services but faster and increasingly moving to unlimited data.
- Wireless broadband services that are simple to set-up and move but are also faster and moving to unlimited data.
- Virtual reality experiences that transport our customers into stadium or arenas anywhere on the globe from wherever they are.
- Connectivity for more of our customers things that is simple for customers to manage – from wearables to home appliances to vehicles.

Our 4G experience also tells us that customers will find new ways to take advantage of 5G technology. When we launched 4G in 2013, we could not have predicted the sharp growth in video traffic on our wireless network. Similarly, we do not yet know the full range of 5G use-cases that might emerge. But already we are aware of a number of potential 5G use-cases that will be transformative in a number of sectors of the New Zealand economy.

As these transformational digital business models and digital services eventuate, we know there will be incremental value in delivering the 5G connectivity that supports them, and further value again in providing the data analytics and management services that will underpin them, because they will allow sectors of our economy to realise significant cost efficiencies that those sectors will value.

Our ambition is to have New Zealand's best and most extendable 5G mobile network in place so when commercial demand for those digital business models emerges, we are ready and primed to extend that network in whatever ways are necessary to enable them.

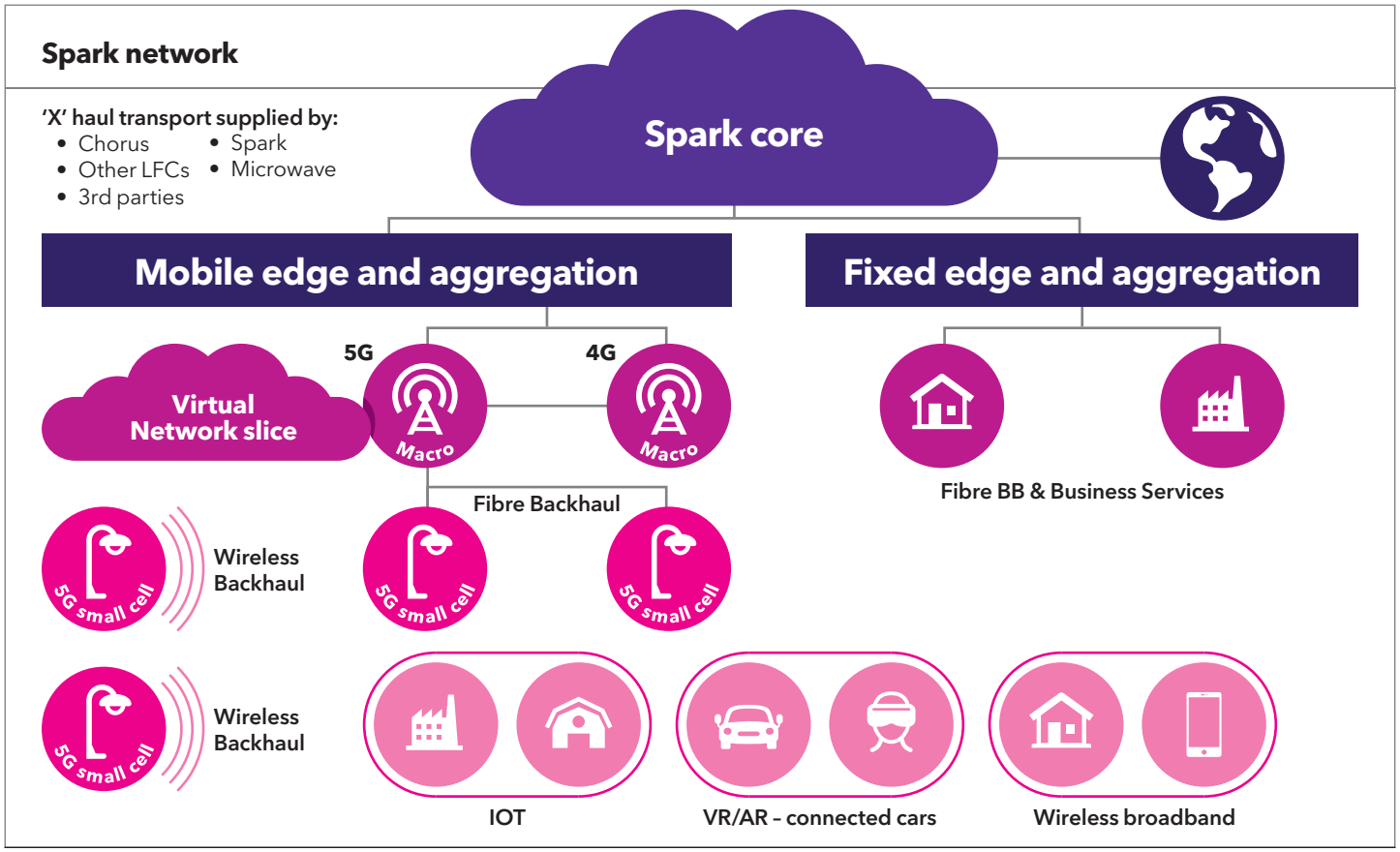
The Network

Spark's 5G services will be delivered over a network comprising cell sites connected by fibre-optic transport or wireless transport links, an upgraded network core, edge computing and a radio access network (RAN).

The evolution to a 5G network will be built in what is termed a 'non-standalone' implementation. This means 4G will continue to provide base coverage to our customers, particularly at the connectivity layer. Advanced services will be enabled with the overlay of a 5G network. The overbuild will involve moving to a distributed network where more network functions are aggregated at points closer to the cell sites being used by customers, with high-quality transport connections back to the main Spark core.

We expect the initial 5G network will focus on using C-band spectrum – not only because this is the first spectrum band likely to be allocated by the Government, but because this mid-frequency spectrum gives the best balance between capacity and coverage. Spark's testing of C-band spectrum shows it has similar signal propagation characteristics (in terms of reach, penetration, etc) as the 1800MHz band spectrum used for 4G. For this reason, 5G services using C-band spectrum initially won't require a large number of new standalone urban cell sites because much of the cell site densification required is already being undertaken (or will be in our plans) as part of network capacity expansion over the next few years.

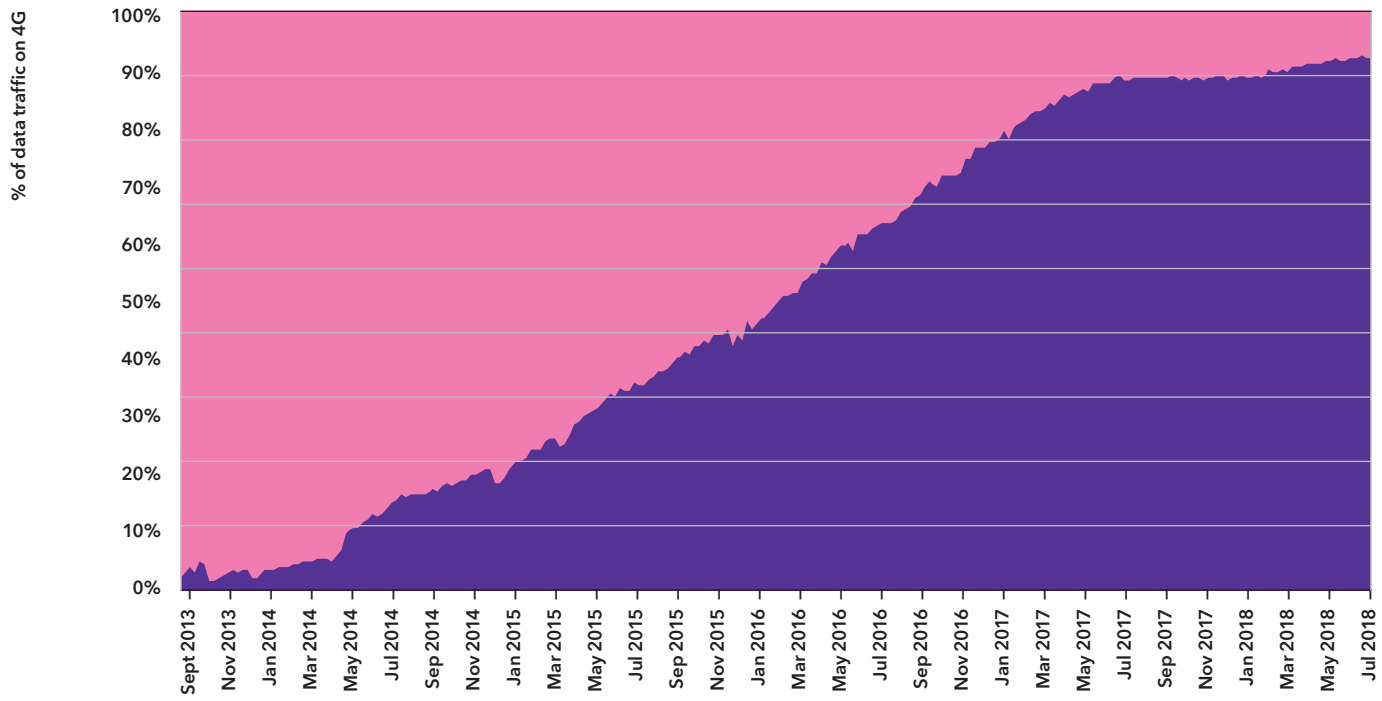
In contrast, high frequency mmWave spectrum enables extremely fast data speeds and high capacity over short distances, which makes it well suited for dense traffic hotspots. Within these hotspots, we will need to build a significant number of new cell sites – however, these will be "micro-sites" not too much larger than what are used today for commercial Wi-Fi services. These microsites can be fixed to "street furniture"



Component	Description	5G Future
Device	The final step in providing the service to the user. Most commonly a handset.	Proliferation of device types including data devices, various sensors, as well as macro-devices (fridges, drones, cars) that have wireless functionality embedded
Spectrum	The radio link from the device to the cell site	New spectrum bands will provide materially higher speeds and network capacity
Radio Access Network (RAN)	Cell sites and the radio access and associated processing components	Cell sites become progressively smaller and more numerous, requiring changes in deployment strategies and in the architecture of the network
Transport Links	In a 5G network, the transport links between the RAN back into the core of the network are called fronthaul, midhaul and backhaul	Fibre will remain the primary means of transport between cell sites, but low latency demands mean transport to the cell edge becomes more time-critical and bandwidth much higher. Smaller sites will require cheaper solutions and most likely get aggregated at a distributed aggregation hub. Wireless options will become more common to feed back to hub sites.
Network Core	The central processing in the network where services are defined and users are authorised. There are two broad functions: the 'control plane' that provides functions such as authentication and service authorisation; and the 'user plane' that routes customer data traffic and provides real-time charging for services	With 5G, the two network core functions need not be co-located as they are today. The network will support Software Defined Networking and Network Function Virtualisation and allow Spark to support multiple service categories within the network core.
Distributed Edge	The point where the cell sites consolidate and connect back to the network over transport solutions to carry data.	5G will operate in a hub-and-spoke environment. Mini data centres will house virtualised network functions and act as a consolidation point for several sites to communication back to the core network. Fibre will be key for linking these back to the main Spark network.

4G take-up by Spark customers

% of data traffic on 4G vs 3G



Source: Spark NZ data

such as lamp posts and power poles, and other locations such as the sides of buildings, making them much cheaper to build than a conventional cell tower. Most likely, these micro-sites will be located in a hub and spoke configuration around a macro-site that uses C-band spectrum.

As our 5G network expands to encompass these micro sites that will be required to provide dense mmWave spectrum coverage, this will require a change in fibre transport services and pricing structures. Similarly, the cost and complexity of installing these micro sites will need to be orders of magnitude lower than that faced when building cell sites today. As an industry we will need to work with central and local government to facilitate low-cost deployment of these lower-impact, smaller-coverage sites ahead of demand for them.

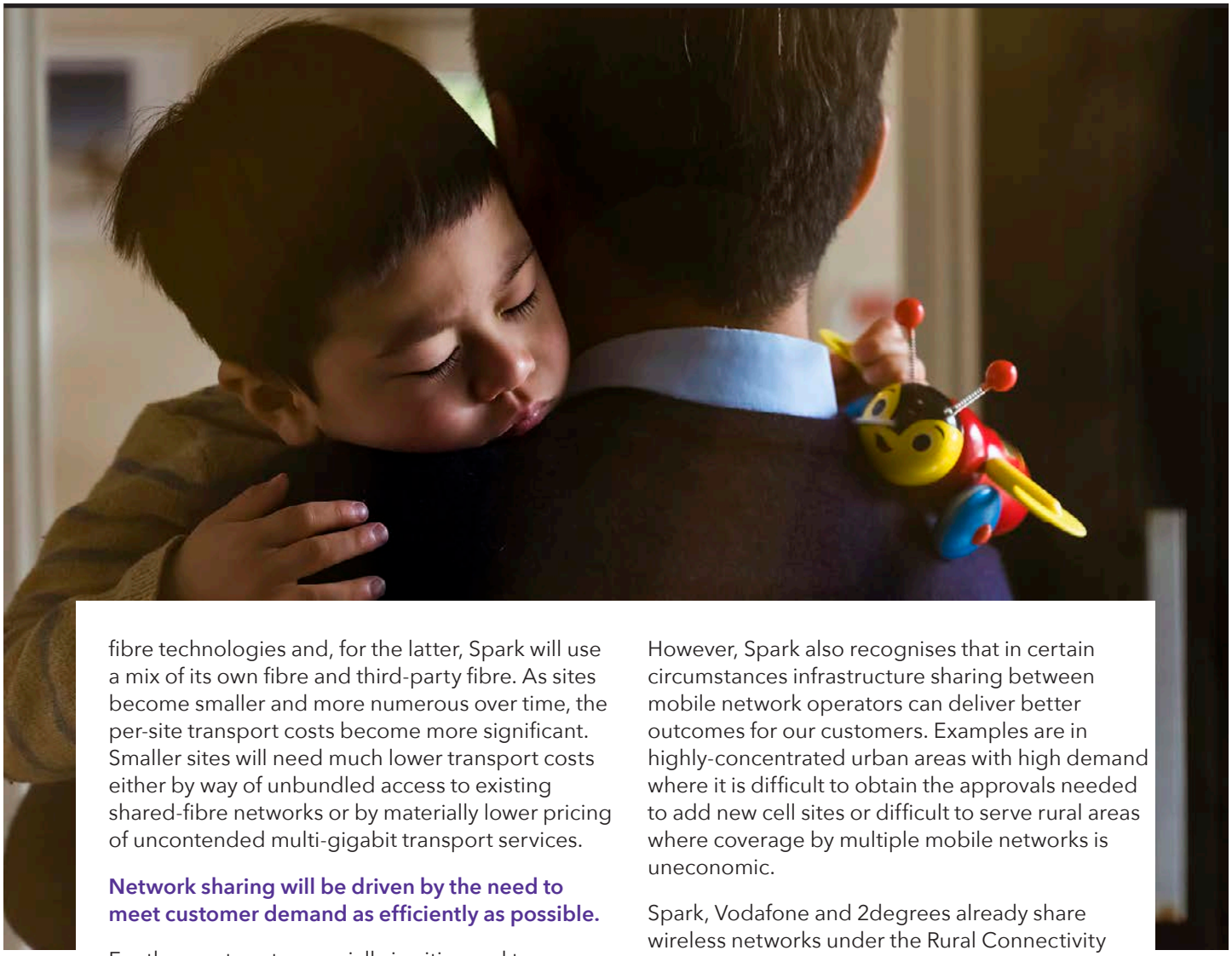
The core of the wireless network represents the centralised processing that provides functions such as authorisation, measurement of customer data use and routing. The core will evolve towards new technologies and some functions will be "virtualised" so they can be moved closer to the network edge. This will be crucial for low latency services such as AR or VR. These functions will increasingly occur closer to customers on generic hardware - what is known as virtualisation. The physical location of such processing will also move outwards to more locations and closer to the end users (edge computing).

The flexibility of 5G has been realised through the ability to "virtualise" functions within the network that enable the provision of tailored services for specific customer needs or use cases. With 5G we move away from the "one-size fits all" paradigm of every previous generation, to one whereby the network exhibits multiple personalities to the services it enables. Different metrics (such as bandwidth, latency and reliability) can be presented to different services.

The 5G network core provides two broad functions: a "control plane" function, which oversees the request to connect by a device and a "user plane" function, which allows the information exchange between devices. These could take place in different parts of the network. For example, with time-critical services like virtual reality or traffic control information, the user plane can be located close to the device location while the control plane can be in a data centre deep within the network.

5G transport is different from 4G in that there are three components – fronthaul, midhaul and backhaul. These will use a mixture of radio and

[2] For more information on the Rural Connectivity Group, refer to http://www.thercg.co.nz/



fibre technologies and, for the latter, Spark will use a mix of its own fibre and third-party fibre. As sites become smaller and more numerous over time, the per-site transport costs become more significant. Smaller sites will need much lower transport costs either by way of unbundled access to existing shared-fibre networks or by materially lower pricing of uncontended multi-gigabit transport services.

Network sharing will be driven by the need to meet customer demand as efficiently as possible.

For the most part, especially in cities and towns, we envisage each wireless network operator will build and operate its own network infrastructure as occurs today with 3G and 4G services. Competition between wireless networks has delivered immeasurable benefits to New Zealand in the last 30 years and competition between 5G networks will continue this trend.

In contrast to the wireless market, fixed line telecommunications in New Zealand is dominated by monopoly fibre and copper access providers, with retailers offering their customers resold connectivity to those networks. As a retailer of both fixed and wireless telecommunications services, Spark has experience operating within both of these market structures. Network competition between competing wireless networks has permitted mobile retailers to offer truly differentiated services and thus dynamic competition and efficiencies to customers. That encourages retailers such as Spark to invest in new technologies and services, providing true choice to consumers.

However, Spark also recognises that in certain circumstances infrastructure sharing between mobile network operators can deliver better outcomes for our customers. Examples are in highly-concentrated urban areas with high demand where it is difficult to obtain the approvals needed to add new cell sites or difficult to serve rural areas where coverage by multiple mobile networks is uneconomic.

Spark, Vodafone and 2degrees already share wireless networks under the Rural Connectivity Group (RCG)[2] to provide wireless coverage in remote areas, and we already share cell towers and some other network elements, as well as spectrum and radio equipment in suburban and urban areas where this is required. As 5G networks are deployed we will continue to look for opportunities to share infrastructure investment with other wireless network operators where it makes commercial sense to do so and where it can extend 5G coverage across New Zealand.

Sharing it is likely to make the most sense in remote areas, where even cell sites using the lowest-available frequencies don't cover enough customers. In these areas, an RCG-style shared network build is likely. Infrastructure sharing might also involve co-location of multiple wireless network operators' equipment on the same cell site. This is like phase one of the Rural Broadband Initiative (RBI), where Spark co-located on many of the RBI sites built by Vodafone under its RBI contract with the Government.

Spectrum

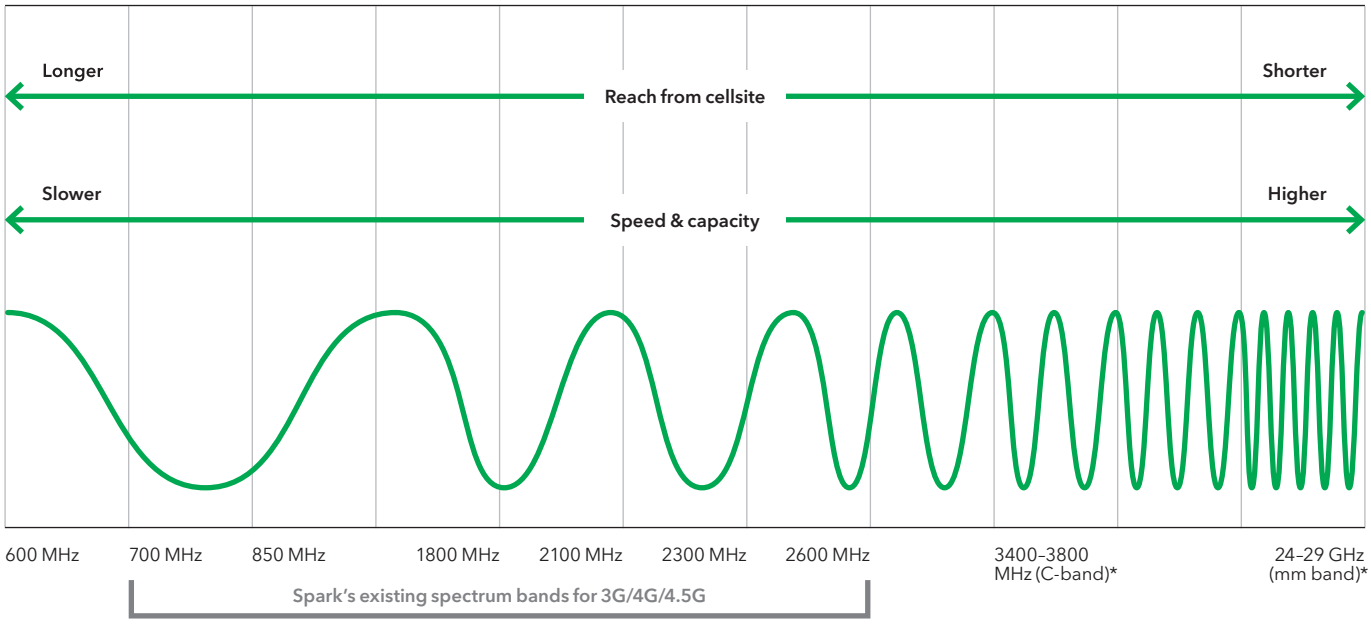
Spark is already making decisions that are contingent on securing additional 5G spectrum and we are having to make those decisions in the absence of any clear policy on when that spectrum will be available or in what bands.

Globally, C-band and mmWave are the most referenced bands for initial 5G deployment. There is enough certainty around them to have a good level of confidence that they will be key parts of the New Zealand 5G ecosystem in the near term.

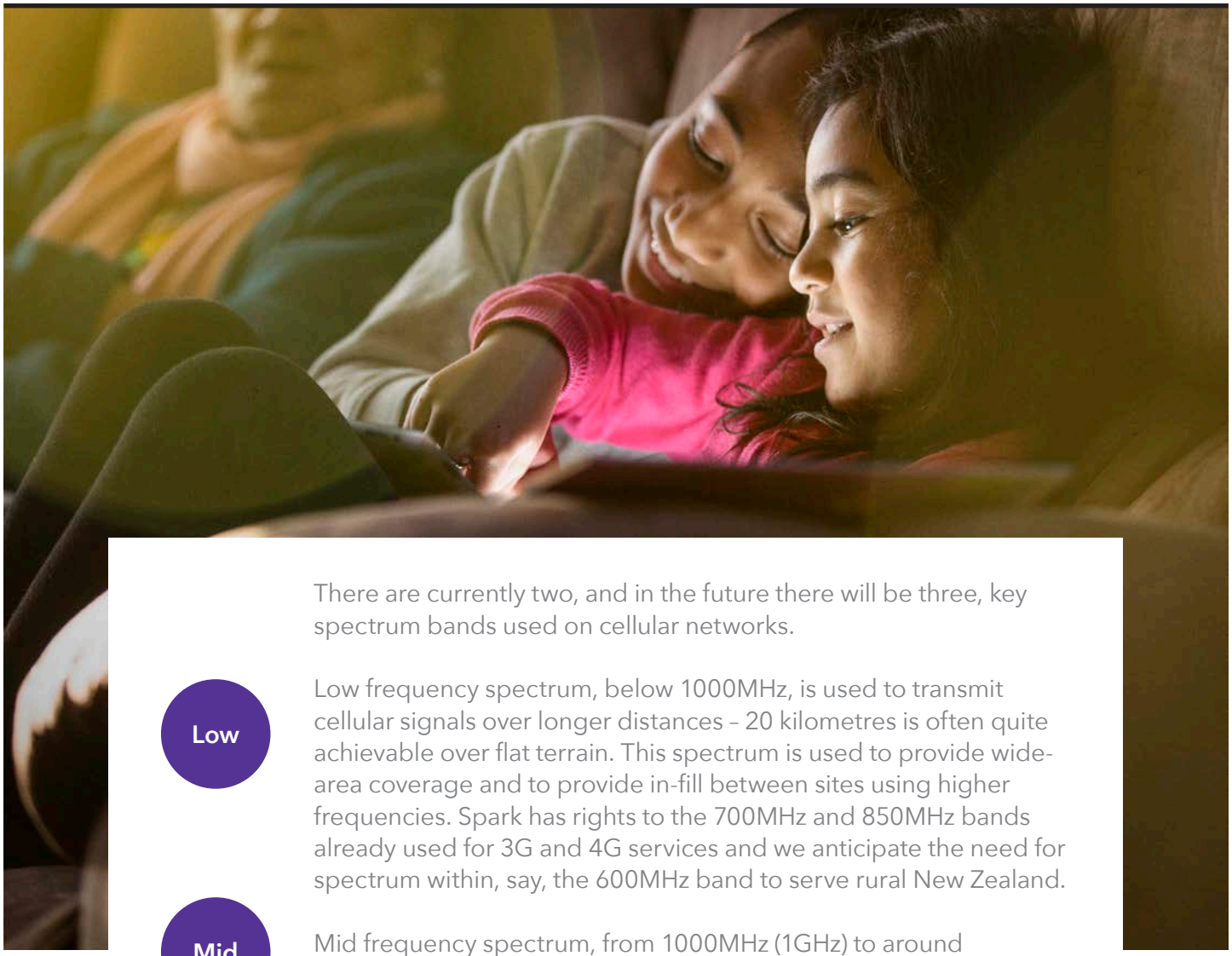
C-band

C-band spectrum exists in frequencies between approximately 3300MHz (3.3GHz) and 5000MHz. In New Zealand, the Government is considering allocating C-band spectrum from about 3400MHz up to about 3800MHz. C-band is an extension of the spectrum used by advanced 4G networks today. The principal benefit it offers to wireless operators and our customers is larger blocks of spectrum than we have been able to use for 4G and preceding technologies. A feature of each new generation of wireless network technology has been the ability to use larger blocks of spectrum; in simplified terms, the more spectrum a network can use the faster the data speeds on that network will be. This means larger blocks of spectrum than wireless network operators have purchased in the past for 4G and 3G networks will be needed to take full advantage of 5G technologies.

Potential 5G bands identified by government



* The Government proposes that C-band (3400–3800 MHz) is top priority for 5G implementation, with mm-wave band (24–29 GHz) a high priority (Ministry of Business, Innovation and Employment discussion document 'Preparing for 5G in New Zealand', March 2018).



There are currently two, and in the future there will be three, key spectrum bands used on cellular networks.

Low

Low frequency spectrum, below 1000MHz, is used to transmit cellular signals over longer distances – 20 kilometres is often quite achievable over flat terrain. This spectrum is used to provide wide-area coverage and to provide in-fill between sites using higher frequencies. Spark has rights to the 700MHz and 850MHz bands already used for 3G and 4G services and we anticipate the need for spectrum within, say, the 600MHz band to serve rural New Zealand.

Mid

Mid frequency spectrum, from 1000MHz (1GHz) to around 6000MHz, is used for the key capacity bands for today's cellular networks. As there is more spectrum available than in the low frequency bands, more cellular traffic, in aggregate, can be carried. This spectrum does not perform as well as low frequency bands in rural areas, although in many cases a small provincial town might have mid frequency spectrum on a cell site to carry the in-town traffic – freeing up capacity on the low frequency spectrum to serve the surrounding area. Spark has existing rights to 1800, 2100, 2300 and 2600MHz bands. In the New Zealand context, 5G C-band is defined between about 3400MHz and 3800MHz.

High

High frequency spectrum, in the mmWave band above about 24GHz, is currently used for point-to-point wireless links and connections to satellites. It has been identified as spectrum for the expansion of 5G because it offers significantly greater capacity than any of the bands currently in use in cellular networks. Its disadvantage is that its reach (propagation) is materially lower than existing bands, so deployment just on existing sites would result in limited coverage. Therefore, it is expected that 5G networks will need to increase their numbers of cell sites over time to provide consistent mmWave coverage – but they will be much smaller, and cheaper to build, than traditional cell sites.

To capitalise properly on this potential, minimum C-band spectrum blocks of 80MHz (and ideally 100MHz) should be available per operator so initial 5G services can deliver data speeds better than what 4G can currently achieve using 2300MHz band spectrum.

mmWave

The other key band for initial 5G use is referred to as "mmWave". In New Zealand, the Government is considering allocating spectrum in the 24.25GHz to 28.35GHz range initially, with some higher-frequency mmWave bands likely to be made available later. This spectrum band is much higher frequency than any currently used in New Zealand for cellular wireless networks and its physical characteristics are quite different. The coverage footprint per site is materially smaller, and the ability to penetrate into buildings, other than through windows, is quite limited. Conversely, the high frequency means even larger spectrum blocks are available - promising extremely high data speeds when users can receive coverage.

To optimise these data speeds, spectrum blocks in the mmWave band should be of at least 400MHz, with the opportunity for an operator to acquire two blocks totalling 800MHz. Subject to spectrum availability, Spark intends to start installing smaller, localised cell sites suitable for mmWave soon after C-band macro cell sites have been deployed.

Spark believes the Government's policy priority should be to make C-band and mmWave spectrum available for purchase and use as quickly as possible, with block sizes of at least 80MHz and 400MHz respectively.

To support the build of new infrastructure and equipment, changes may be required to planning practices. We support the Ministry for the Environment initiative to develop a utilities planning standard under the Resource Management Act[3], setting out the policies and rules for network utilities. These will potentially replace separate district plan requirements.

We see commercial use cases for each of these bands in the near term and it's imperative New Zealand keeps pace with international 5G deployments. Key policy decisions on this need to be made in 2018 and spectrum auctions need to occur during 2019.

Low frequency spectrum

Looking further ahead, the first low frequency spectrum we expect to see released for 5G use in New Zealand is in the 600MHz band, some of which is currently used for broadcasting services. Other spectrum bands at frequencies below 600MHz might also be considered in future for 5G, as they would have similar signal reach that would make them suitable for rural cell site deployment.

Although good service can be provided to customers sufficiently close to a C-band or mmWave spectrum cell site (including those in small provincial towns), in most rural areas there are often many customers too far from any site for these bands to be effective. Spark is responding to this in two ways:

- We have advocated for the release for cellular use in New Zealand of 600MHz band spectrum. This will have even better reach than the present preferred 700MHz rural spectrum band. T-Mobile in the USA is expected to offer services using the 600MHz band from 2019.
- We have built a LoRa[4] network to provide deep, wide-area coverage for sensors and other IoT devices with applications in the rural sector. This ensures we can efficiently deliver certain IoT applications to the rural sector in advance of a 5G network rollout.

Spark is already making decisions that depend on securing additional 5G spectrum and we are encouraging the Government to make clear policy decisions on what spectrum will be made available, and when, for 5G services in New Zealand.

Environmental concerns

One of the concerns relating to cellular technology is the impact of electromagnetic fields (EMF) generated by cell towers and related equipment.

In New Zealand these are governed by the New Zealand Standard NZS2772 recommended by the Ministry of Health (MoH) and mandated under the Resource Management Act. The New Zealand standard sets maximum public exposure levels that are more than 50-times lower than the recognised threshold for established effects.

Spark designs all its mobile sites to comply with this standard and employs independent monitoring to ensure ongoing compliance. Monitoring to date shows average EMF exposures are, in practice, a very small fraction of the levels set in NZS2772.

It is expected that New Zealand and international agencies will continue to monitor the effects of 5G deployments as networks are rolled out and to explicitly consider whether any change to the standard is required. Spark's deployment of 5G will follow the standards set by MoH and international bodies.

[3] The Planning Standard for Infrastructure and Roading
[4] LoRa is a Low Power, Wide Area wireless network. It is not a 5G network, but can be used to supplement 5G network coverage for IoT devices.

Network Investment

User demand is growing rapidly on our 4G networks and we are continually adding capacity - 4G spectrum carriers, sites and sectors - but this will take us only so far.

With our customers' ever-growing thirst for data services resulting in wireless network demand roughly doubling each year, 5G will enable us to provide additional capacity at a lower incremental unit cost than continuing to expand 4G capacity would.

This means that once 5G is available, we will have a strong commercial incentive to rapidly build 5G network capability as the primary means of keeping ahead of growing customer demand. Based on current network traffic growth rates, we anticipate that by 2020-21, 5G will be our preferred solution for capacity augmentation – let alone for the anticipated demand growth from new applications made possible by 5G.

We expect our 5G network development to be funded within Spark's existing capital expenditure envelope (excluding spectrum and any material outlay required for a more widespread move to mmWave), as we divert spend from 4G capacity expansion into 5G as soon as we have the necessary spectrum.

As Spark responds to demand we will be investing just ahead of it. Cost efficiency that will deliver ever-greater output with the same investment inputs is the primary driver of early 5G deployment. By 2020, we expect our wireless-network specific capex to be between 25%-35% of Spark's overall capex envelope. This implies intended annual wireless network investment of approximately $100m to $140m, compared with an average of just over $100m for the past five years. This excludes spectrum purchases and any material move towards widespread rollout of new cell sites using mmWave band spectrum. During this period, we expect our total capex (excluding spectrum) will remain in line with our desired range of 11%-12% of revenues.

Revenues from wireless connectivity are expected to increase only moderately over the first few years of 5G deployment, in line with recent trends. From about 2023 onwards, there is potential for further upside as customer demand grows for new capabilities, rather than just more capacity and speed.

5G is expected to be deployed initially as an evolution of existing 4G/4.5G networks relying on the existing network to ensure comprehensive coverage. Some services, such as voice and emergency calling, rely on the existence of a 4G network.

As further demand growth intensifies and new use cases for 5G emerge, particularly those based on URLLC and eMTC, Spark will continue to invest in additional standalone capability and further densify the access network to add capacity.

5G and competitive markets

Wireless competition in New Zealand is vigorous and has served the country well.

Not only is the price of service packages low but coverage is expensive to provide, so the outcomes in this country are particularly impressive.

This comes down to competition, which has featured a constant trend of infrastructure upgrades and innovations as the three wireless network operators have vied for market position. The result has seen significant benefits to consumers and the same competitive approach will best deliver efficient 5G infrastructure and future technology upgrades for New Zealanders.

In addition to delivering great outcomes for consumers, a competitive market structure in New Zealand is the most cost-effective solution for taxpayers – because the private owners of the wireless network operators assume the vast majority of investment required to build new networks and expand capacity. Over recent years, the collective investment by the three existing operators in direct network infrastructure, plus associated spectrum rights, has averaged $400 million per year. On top of this, they have invested hundreds of millions more dollars in core technology systems to improve the delivery of services across their respective wireless networks.

The Government is subsidising the rollout of wireless networks into rural New Zealand where sparse populations and challenging terrain mean services cannot be provided on a normal commercial basis. Overall, however, the wireless sector has been a net contributor of revenue for the Government:

- In the decade 2012 to 2022 (based on investment to date and already-announced commitments) the Government will contribute almost $400m towards improved wireless networks as part of the Rural Broadband Initiative (RBI).
- During the same period, the Government has already raised a total of $420 million from the industry from auctions of 3G and 4G wireless spectrum rights (before future revenue from any 5G spectrum auctions is taken into account).
- Moreover, about $250m of the Government's RBI funding is coming from the Telecommunications Development Levy, through which the broader industry collectively pays a $50m annual levy (each provider is levied according to its share of total market revenue, with Spark's share almost $20m annually).
- By comparison, over the same 2012-2022 period, the Government will contribute approximately $2 billion of taxpayer funding towards improved fixed network services, through the UFB and RBI programmes.
- Both the fixed and wireless network deployments have improved coverage and services for New Zealanders, but it is the competitive environment of wireless networks that has meant that those benefits have been delivered largely without the need for a taxpayer subsidy.

All other countries that are shaping up as early adopters of 5G are also using a competition-based industry structure to generate competition and innovation.

Spark believes it is essential that wireless operators have end-to-end control of their networks so they can deliver services in new ways including network slicing.

The specifications of 5G have been designed to provide quite distinct and often conflicting service requirements, so the way to cope with this is to slice functions of the network tailored to the performance characteristics of that service. For example, massive IoT connections will require centralised processing but the low latency required for AR / VR will required processing closer to the customer. Network slicing is defined as an end-to-end capability – meaning that to truly guarantee the service level of a network slice, the operator must be able to stitch together the relevant components across RAN, Transport and Network Core.

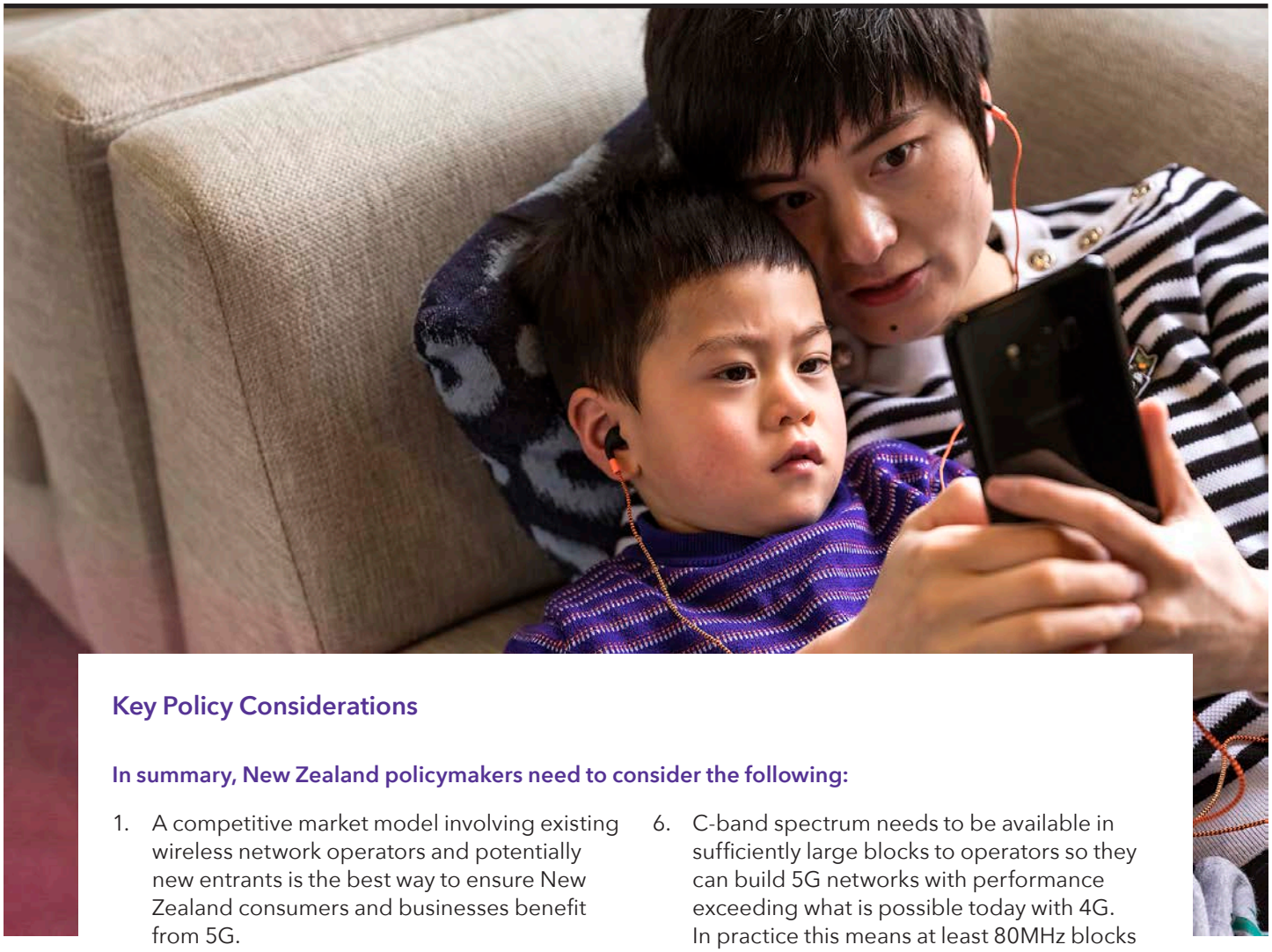
Competition does not mean unnecessary infrastructure proliferation. It means demand-driven expansion to meet customer needs and to maximise the network capabilities, and to create innovation and client-specific services that will get the best from 5G.

In practical terms, multiple competing networks will not necessarily mean significantly more infrastructure, such as cell towers, compared with a single monopoly network, because infrastructure is driven by the amount of data it has to carry. Single towers having to carry more traffic potentially means bigger towers to meet the demand, which may present environmental challenges especially in urban areas.

Spark considers the suggestion by Chorus that the Government should contemplate a monopoly, open-access network approach for 5G is founded on incorrect assumptions about the way 5G technology will show up for New Zealanders. As discussed in this paper, 5G is best seen as an overlay and advancement of existing wireless technologies, not as a standalone network.

Any policy moves towards a monopoly radio access network would create significant industry uncertainty and would likely slow down the introduction of 5G to New Zealand by years. Chorus would need to build its own cell site network (or arrange to access cell sites owned by other operators) and either build its own network core from scratch or force complex integration with other wireless network operators. This would result in the replication of network infrastructure rather than leveraging the existing assets of New Zealand wireless network operators - and have the effect of reducing 5G network competition to a common denominator.

This is not to say there aren't opportunities for Chorus to be involved with 5G. There is a potentially attractive role for Chorus, as well as the local fibre companies, to use their extensive UFB fibre networks to provide high-quality transport links from 5G cell sites and distributed aggregation points in commercial arrangements with wireless network operators.



Key Policy Considerations

In summary, New Zealand policymakers need to consider the following:

1. A competitive market model involving existing wireless network operators and potentially new entrants is the best way to ensure New Zealand consumers and businesses benefit from 5G.
2. A holistic view needs to be taken of the environment within which 5G investments will be made. Wireless networks are integrated systems and they evolve over time
3. Innovative transport solutions will become increasingly important as cell site counts increase. New solutions such as the use of shared-fibre networks and point-to-point wireless may be required to make small-cell sites economic. Regulatory support may be required to obtain fair access to network assets that are not provided directly by Spark.
4. Changes may be required to planning practices to support the build of new infrastructure and equipment, with the development of a new planning standard under the Resource Management Act.
5. C-band and mmWave spectrum work in unison on a 5G network and need to be considered in the same context and not as separate functions.
6. C-band spectrum needs to be available in sufficiently large blocks to operators so they can build 5G networks with performance exceeding what is possible today with 4G. In practice this means at least 80MHz blocks and ideally 100MHz blocks available to an operator.
7. mmWave band spectrum should also be released as soon as possible, as it is required to realise the full benefits of 5G for New Zealand consumers and businesses in tandem with C-band deployment. To optimise data speeds, spectrum blocks in the mmWave band should be of at least 400MHz, with the opportunity for an operator to acquire two blocks totalling 800MHz.
8. The C-band and mmWave allocations should be completed as soon as possible, to ensure 5G services can be delivered in time for the 2020-21 America's Cup in Auckland as an international showcase opportunity.
9. Regardless of operator, low-frequency spectrum will be required to deliver the benefits of 5G on a widespread basis into rural areas (beyond small provincial towns). The work to define 600MHz as a spectrum band applicable to cellular networks should continue at pace.

Beyond 5G

We think we're well on the way to leading New Zealand into a 5G world.

But mobile technology evolution never stops and even before we've started deploying commercial 5G networks, technologists, international standards bodies, and the wider mobile industry, are starting to think about the next generation of mobile technologies again – 6G. So what is 6G - or more accurately, what might it be?

More Data, More Spectrum

Just as 5G technology can deliver data faster and use larger spectrum blocks than 4G, 6G will increase data speeds and spectrum block sizes again (provided that sufficient spectrum is made available). So we expect to see an order of magnitude increase 6G relative to 5G - meaning speeds in the tens of gigabits per second.

New Applications: 'the Internet of Very Small Things'

Many of the applications being envisaged for 6G today tend to be similar to those already identified for 5G – IoT, smart cities and transport systems, and automated vehicles or equipment – but they are likely to be on a much grander scale. If 5G will bring us a world of "connected things", it is very possible that 6G will extend that concept to the micro scale. More and more people are projecting that 6G will be the first generation of cellular technology to be designed for nano devices and bio devices. Where 5G may connect lightbulbs in the home or in the streetlight, 6G may connect the contact lenses we wear in our eyes.

Fully-integrated Artificial Intelligence (AI)

The possible scale of micro/nano technology, and the complexity of the networks that will be required to connect that scale of devices, is extraordinary. Which means 6G networks will need to be even more intelligent and autonomous than 5G networks. Near-ubiquitous, instantaneous, connectivity, combined with artificial intelligence, is predicted to play a big part in how 6G networks are managed and operated.

Conclusion

6G today is still a research topic. Much of the technology to enable it isn't expected to become a commercial reality for 10 years or more. And right now, it looks a lot like an extension of 5G. But as new technologies continue to emerge, especially in AI, materials, and nano and bio technology, there is room for 6G to let us realise concepts and services that today exist only in science fiction. A flexible, dynamic industry structure will be important to ensure New Zealand's future networks can adapt to and implement new technologies as they emerge.

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