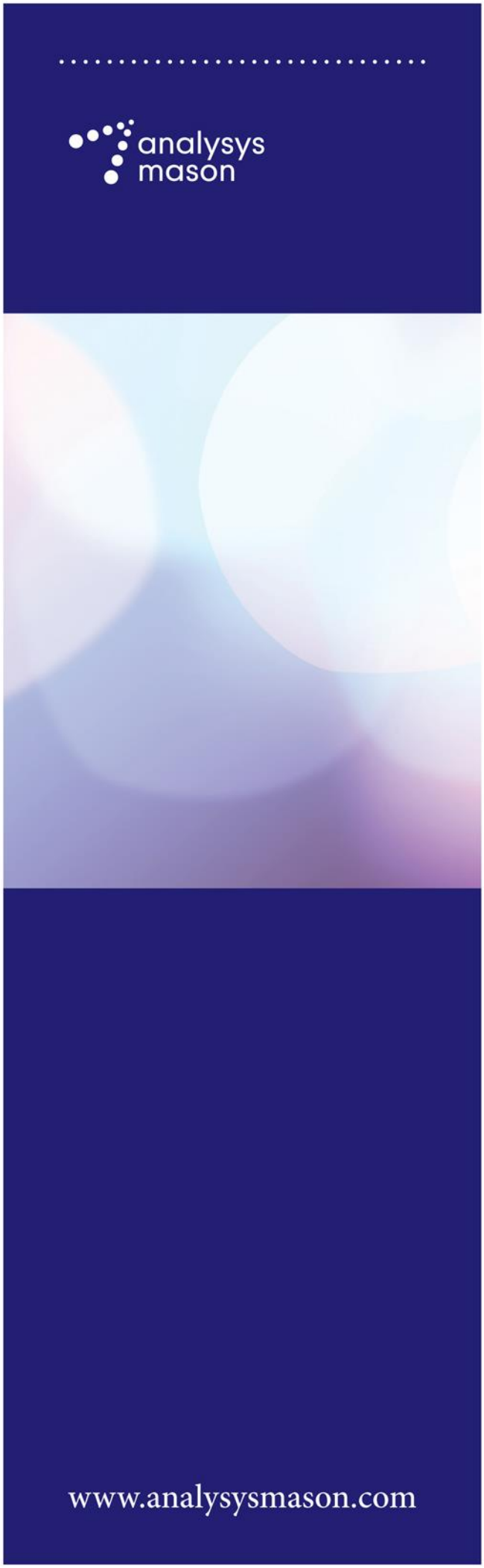


Report for Trustpower

Input to Commerce Commission mobile market review

28 November 2017

Ref: 2011838-481

1 Introduction

1.1 Context

We understand that the Commerce Commission is about to undertake a study of the mobile telecommunications markets in New Zealand, seeking to understand better how mobile markets are developing and performing, with a view to developing a common understanding of the forward looking competitive landscape for mobile telecommunication markets along with any emerging competition issues.

We further understand that the Commission expects its study to:

- identify consumer preferences and how they appear to be evolving;
- identify how mobile providers are responding to:
  - that evolution in consumer preferences; and
  - technological shifts in how mobile services can be delivered;
- consider the impact of these trends on the performance and development of mobile services, including any obstacles to market development and any current or emerging competition effects; and
- consider, to the extent we might identify any relevant issues, how our regulatory tools could be applied for the long-term benefit of end-users.

The Commission is currently engaging with interested stakeholders, requesting their input, before finalising the scope, sequencing and timetable for its work.

This paper forms a response to this request.

1.2 Overall summary

We support the aim of the Commission's review. We recommend that the Commission considers a wide scope within its review. This will allow the review to encompass the wide variety of possible future market changes and the number of different ways in which the decisions of the Commerce Commission (and the NZ Government more widely) can and will affect the development of the communications industry.

The long-term interests of end users (LTIEU) can be better served in the following ways:

- The dynamic efficiency benefits of competition are not yet felt as strongly as they might be in the mobile market in New Zealand: a more dynamic retail market would bring benefits in terms of product and service innovation as well as competitive pricing. This can be aided by more retail players making use of new wholesale arrangements and new technologies.
- Lower unit costs and/or additional service coverage at current unit costs can in future be delivered by: making greater use of network sharing; using additional spectrum (some of which

may be dynamically shared with other uses); making more efficient use of the spectrum already available; and through innovations in devices and network technology.

- These innovations may extend to new styles of network deployment and new wholesale models, each of which may enable or support additional types of retail player (improving dynamic efficiency), as well as enabling new types of services. These may include bundles of services bringing together fixed and mobile elements, and services designed for specific classes of users, for example: supporting the emergency services; connected and autonomous vehicles (CAV) or the Internet of Things (IoT).

Many of the forthcoming changes to underlying network technologies are (individually) evolutionary in relation to the current mobile market. For example, massive multiple input-multiple output (MIMO) technologies can be deployed simply to increase the capacity available on existing towers providing wide-area coverage, and tiny Internet-connected base stations ("femtocells") or, in the 5G era, millimetre-wave small cells can be used to increase in-building coverage. However, these changes can also be revolutionary:

- For a subset of end users, the high capacity of massive-MIMO-enabled mobile networks might be sufficient to allow them to become or remain mobile-only (or use "fixed wireless" services) even in an environment where the majority of end users adopt ultra-high speed fixed services at home.
- Using femtocells or licensed small cells allows a new kind of mobile network deployment, the so-called "inside out" network which starts from a femtocell in each end-user's home connected to the Internet; wide area coverage is either rented (using a "national roaming" commercial arrangement) or built on fewer towers given that the network will not need to build as much capacity for in-building use.

Patently however these divergent futures (one with a fixed network connection at home, and one which does not have a fixed connection at home) will not both happen for the same customers.

The Commission should therefore take care to consider the potential wider impacts of specific changes on the entire market, including the combined effect of technological, commercial, and network architecture changes rather than starting from a position that believes the future will be very much like the past.

1.3 Structure of this document

The remainder of this document contains comments on a series of topic areas, concluding each with a discussion of the potential impact on the long-term interests of end users. The topics we examine are: current market structure; network technologies, architectures and deployment styles; wholesale and retail arrangements; new device technologies; convergence of fixed and mobile networks and services; and spectrum bands and licensing.

2 Comments

2.1 Current market structure

2.1.1 The New Zealand mobile market is relatively highly concentrated in revenue terms

Despite decreasing slightly over the past few years, New Zealand's mobile market concentration (in revenue share terms) remains high compared to a set of benchmark countries.

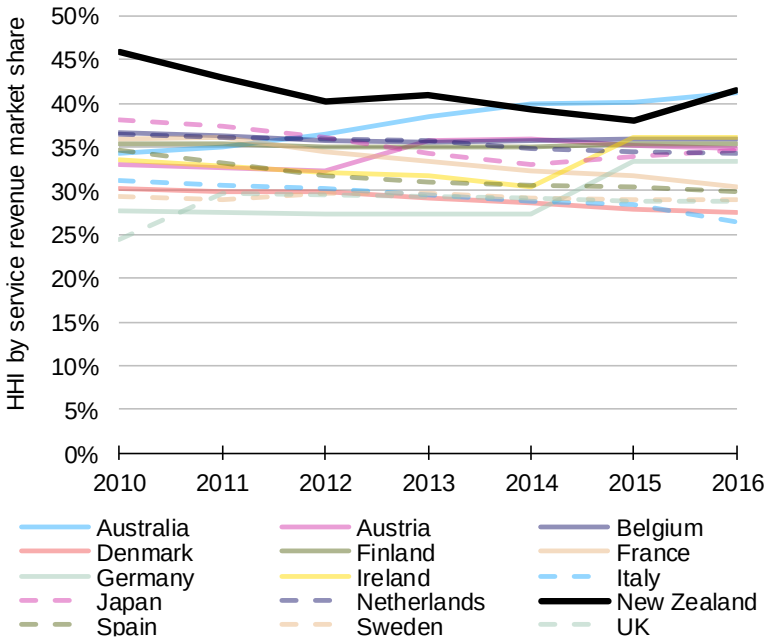


Figure 2.1: Herfindahl-Hirschman Index (HHI), by market share of mobile service revenue [Source: Analysys Mason Research, GSMA]

2.1.2 ARPU in New Zealand is growing, which is against the trend

As shown Figure 2.2 below, in 2010 New Zealand had the lowest ARPU of our group of peer countries in nominal, PPP adjusted USD terms. However, this is no longer the case; ARPU has risen slightly over the last few years in New Zealand, while in a group of peer countries it has generally fallen.

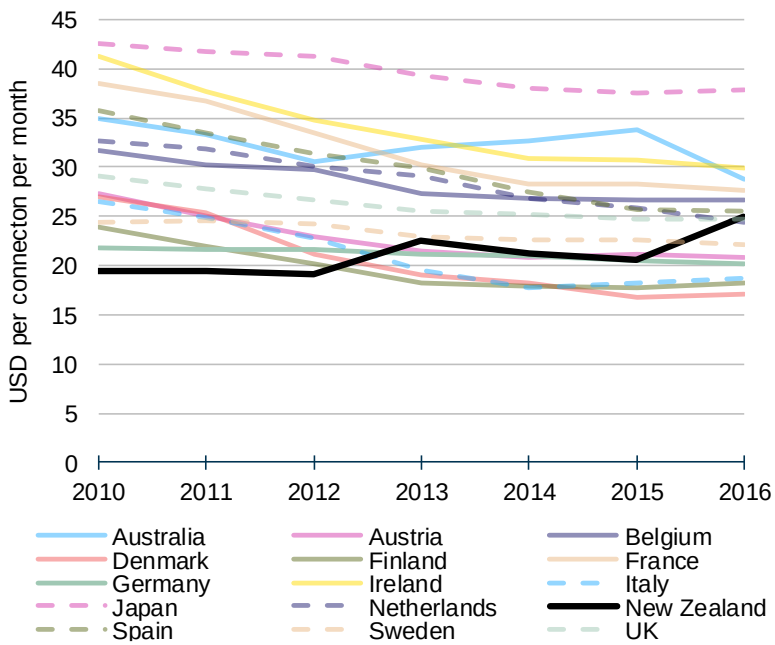


Figure 2.2: Mobile ARPU[1] (mobile service revenue per connection per month), nominal USD adjusted for PPP[2] [Source: Analysys Mason Research - DataHub, GSMA[3], World Bank]

2.1.3 Mobile virtual network operators (MVNOs) are not a significant fraction of the market

New Zealand's three MNOs (Vodafone, Spark and 2degrees) are the country's only significant mobile retailers. The total number of MVNO subscribers increased in 2016 but remained low at around 23,000'[4]. This puts New Zealand firmly at the bottom (in terms of MVNO subscriber share) of a group of peer countries. As shown in the figure below, over 20% of mobile connections are provided by an MVNO in countries such as Germany and Belgium.

1 ARPU is calculated using Analysys Mason Research data as mobile service revenue divided by year-average (active) mobile connections. Mobile service revenue includes termination (interconnection and roaming-in) revenue, but excludes revenue from direct equipment sales. It includes only revenue billed for by operators (or their service provider and MVNO partners) and excludes mobile service revenue that is billed for separately by third parties, such as content providers.

2 Revenue figures are provided by Analysys Mason Research in nominal USD terms, and have been adjusted for PPP using World Bank data (see World Development Indicators - http://data.worldbank.org/indicator/PA.NUS.FCRF?end=2016&start=1994)

3 GSMA data is used for New Zealand. The GSMA defines mobile service revenue as recurring revenue generated in the period, including revenue generated from the use of the network (voice, messaging, data, VAS), but excluding non-recurring revenue such as handset or equipment sales

4 See p22 http://comcom.govt.nz/regulated-industries/telecommunications/monitoring-reports-and-studies/monitoring-reports/

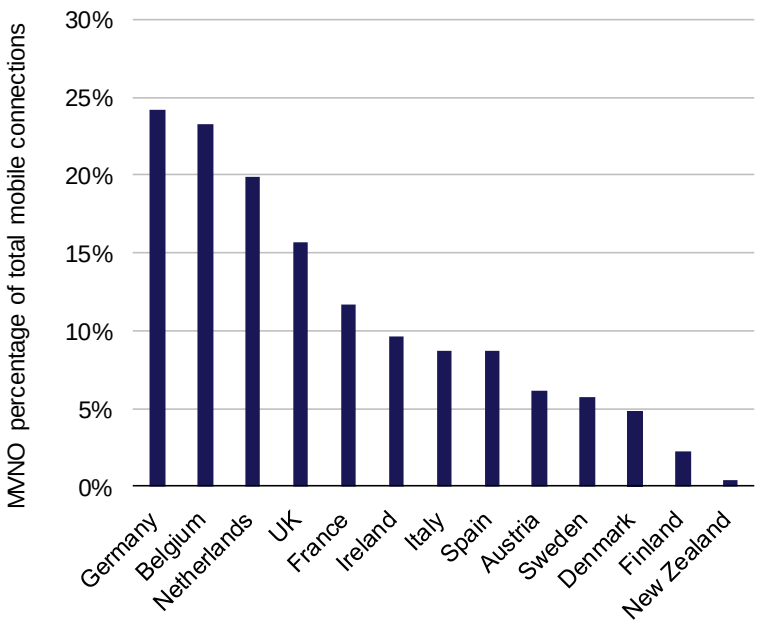


Figure 2.3: MVNO connections[5] as a percentage of total mobile connections[6], YE 2016 [Source: Analysys Mason Research - DataHub, 2017]

2.1.4 Relevance to LTIEU

The dynamic efficiency benefits of competition are not yet felt as strongly as they might be in New Zealand: a more dynamic retail market would bring benefits in terms of product and service innovation as well as competitive pricing. This can be aided by more retail players making use of new wholesale arrangements and new technologies.

2.2 Upcoming and/or recent developments in mobile retail services

2.2.1 Smartphone use of OTT IP-based communications is growing strongly in other countries

Use of over-the-top (OTT) IP-based communications has increased significantly over the past few years, with strong growth in the use of apps. As shown in the figures below, both OTT messaging and OTT VoIP traffic have been growing strongly across a group of European markets since 2010. We do not have figures for New Zealand on the same basis.

5 The number of subscribers to mobile services provided by MVNOs. The figures provided are as reported – that is, they can be either active or registered subscribers. Analysys Mason Research aim to exclude MNO sub-brands, though this is not always possible due to reporting conventions (notably in the case of KPN, Germany and the UK). Joint ventures between MNOs and third parties where the MNO is a majority shareholder are classed as MNO retail operations; 50/50 or minority holdings are classed as MVNOs. Resellers are included in the case of Germany and the UK.

6 Mobile connections exclude M2M/IoT, and are only counted if 'active'. Active connections exclude customers who have not used their mobile account for more than 3 months.

Figure 2.4: IP-based OTT messages sent from smartphones per day per head of population [Source: Analysys Mason Research[7], 2017]

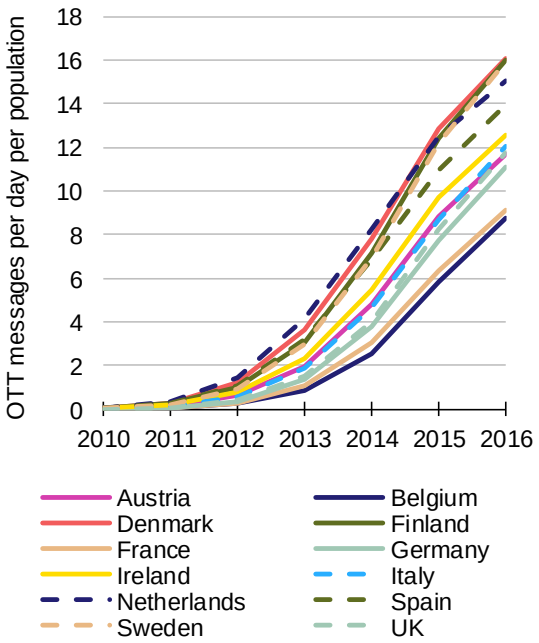
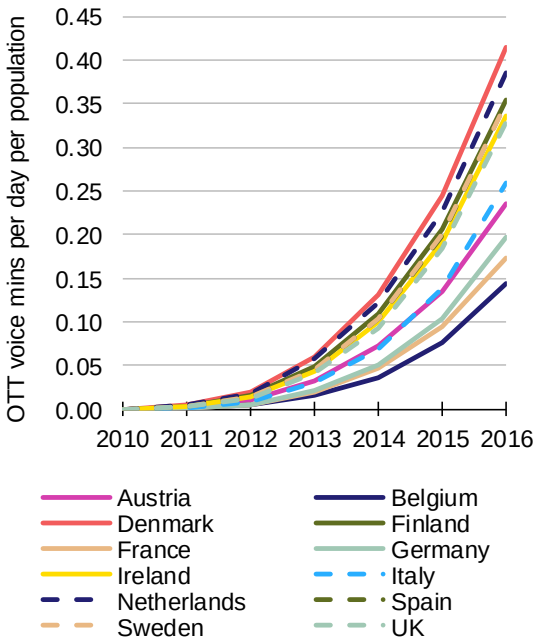


Figure 2.5: VoIP OTT outgoing voice minutes from smartphones per day per head of population [Source: Analysys Mason Research[8], 2017]



2.2.2 Multi-play converged fixed-mobile bundles are growing, and are a very significant part of the retail market in some countries

Figure 2.6 below shows household penetration of accounts supporting mobile, fixed pay TV and fixed broadband (similar to the bundle called "quadruple-play" by some analysts - which also includes fixed voice line rental) for a selection of European countries. While there is a large variation in the popularity fixed-mobile converged (FMC) bundles between countries, take-up of these multi-play bundles has been significant in some markets (notably France, Spain and Portugal).

7 Analysys Mason Research 'Communication services in Western Europe: trends and forecasts 2016–2021'. See http://www.analysysmason.com/Research/Content/Reports/communication-services-WE-Aug2016-RDMV0/#08%20August%202016

8 Ibid.

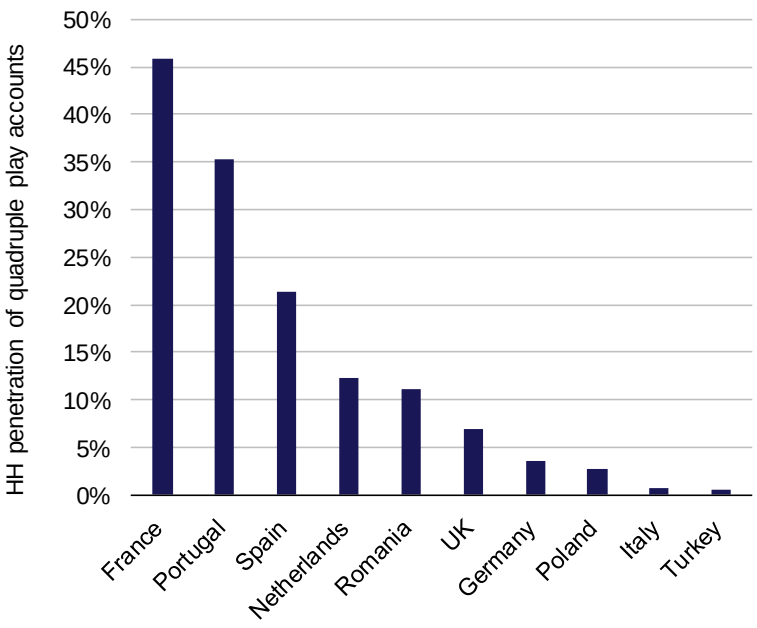


Figure 2.6: Household penetration of accounts for mobile, fixed broadband, and payTV[9] [Source: Analysys Mason Research[10], 2016]

2.2.3 Relevance to LTIEU

These developments show what New Zealand end-users may want to purchase (and what service providers are likely to wish to supply) in the short-term. The question for the Commission is how best to enable these needs to be met in an economic fashion. We note that converged bundles of services may mean that fixed service providers without their own mobile network may need access to wholesale mobile inputs in order to provide such offers to their customers.

2.3 Network technologies, architectures and deployment styles

2.3.1 Deployment styles

Mobile networks deployed over the last 30 years have mostly followed the same overall model, with a large number of base stations deployed on towers or rooftops, providing a layer of wide-area outdoor coverage (the ‘macro’ layer), later followed by and supplemented by a number of smaller cells managed by the operator such as “microcells” and “picocells” for areas of dense demand (shopping malls, major transport intersections, etc). These networks often use leased lines or similar point to point dedicated network links for “backhaul” to the core network. Originally, a separate base station was deployed for each technology at each site; more recently, base stations combining 2G, 3G and 4G equipment are deployed (so-called “single RAN”).

9 Fixed broadband + pay-TV + mobile are fixed-mobile converged (FMC) bundles that include all three services in a plan and may or may not include fixed voice services. Within mobile services, handset and mobile broadband device SIMs are counted. This is the closest metric published by Analysys Mason Research to what is often referred to as "quad-play" in most (but not all) contexts.

10 Analysys Mason Research 'Multi-play services in Europe: trends and forecasts 2016–2020' - updated in August 2016. See http://www.analysysmason.com/Research/Content/Reports/multiplay-services-Europe-Aug2016-RDCS0/#30%20August%202016

As in-building coverage has become more important, and as Internet penetration has increased, some operators (particularly those with fixed retail ISPs) have used Internet-connected "femtocells" as a means of providing in-building coverage. An alternative deployment style is now to use femtocells or other forms of licensed small cells at the beginning of the network deployment, with either a smaller capacity macro layer, or smaller coverage macro layer and a national roaming deal (or both) to provide outdoor services. This deployment model is called "Inside out" and has been enabled by miniaturisation, mass market broadband Internet access, and new spectrum bands; it relies on Internet connectivity already purchased by the end-user for its backhaul. Voice over WiFi can offer a similar model for supported handsets.

A further new style of development is starting to be deployed, driven by the need for smaller cells to provide higher capacity density and better in-building coverage. This "centralised RAN" deployment style uses small remote radio heads (or remote radio units, RRU) and centralised baseband processing. The remote radio heads still require power and a high point such as a rooftop, but are much smaller than an entire base station, and are linked to the centralised baseband processing using so-called "front-haul" links. These front-haul links are usually provided using fibre networks as the speeds required are high; the UFB infrastructure available in the more populated parts of New Zealand is highly relevant. If the baseband processing is highly centralised, and runs on commodity infrastructure, then this is called "cloud RAN".

2.3.2 Radio technologies

There is a continuous process of development of the existing cellular standards (LTE, LTE Advanced) and new specifications being introduced for 5G (e.g. 5G new radio, or 5G NR). These newer specifications usually enable higher spectral efficiency. Additionally, the use of new spectrum bands (such as LAA enabling use of unlicensed spectrum) and/or new forms of licensing such as shared access (e.g. MulteFire and CBRS, see below), combined with existing bands (e.g. using carrier aggregation) enables higher capacity and/or increases in peak speeds. Support for multiple generations of radio technology in combined base station units ("single RAN") also reduces deployment costs.

All of these developments have the potential to be used to increase the quality of the user experience, and the level of dynamism in the retail market. Some can be used to either reduce unit costs or to increase coverage at a constant level of unit cost.

2.3.3 Massive MIMO

Multiple Input Multiple Output (MIMO) is a technology which increases the throughput possible in a given amount of radio spectrum. It works by using multiple antennas both to transmit and receive, in order to use multiple independent transmission paths between the sender and receiver. LTE systems already support MIMO.

Massive MIMO extends this by using very large numbers of antenna elements; the net result is that the system capacity is substantially higher but the antenna system will be physically much larger

than current antennas, if deployed in the sub-3GHz frequencies bands typically used for cellular mobile today. These antennas may be more visually intrusive and may require additional strengthening of towers due to the impact of higher wind loads on the larger antennas.

In the 5G era, use of millimetre-wave bands will mean that massive MIMO technology can be exploited at frequencies where the physical size of antennas will not need to be so large. In combination with smaller cells, this has the potential to greatly increase the capacity that can be delivered using a given amount of spectrum, potentially to the Gbit/s level per cell; in turn this could make mobile technologies (providing either mobility or "fixed wireless" services) compete directly with fibre-based fixed broadband services in the home for a subset of end users.

2.3.4 Next generation voice over data networks: OTT voice, VoLTE, VoWiFi

Next-generation networks carry all services over a common network. This includes voice. Such voice services can use either unmanaged or managed data bearers in a number of ways:

- Voice over LTE (VoLTE) is a managed voice service provided by a 4G MNO, using LTE as the means of data transport. MNOs with suitable networks can use 2G or 3G voice as a fallback if LTE is not available.

- VoWiFi is the provision of mobile voice using the home or office building's own WiFi and the Internet. In effect it is an application integrated into the handset (plus equipment within the cloud, which interfaces to the MNO network) to provide a managed voice solution (but using an unmanaged WiFi /Internet connection). It is supported by many modern smartphones. This has been marketed by some MNOs as an in-building coverage solution (e.g. as an alternative to an operator-provided femtocell). VoWiFi is thus an example of many of the trends illustrated in this document:

  — Using the fixed network plus wireless at the edge in this way illustrates the convergence of fixed and mobile network architectures (highly capillary fixed network links plus wireless at the edge)
  — Using unlicensed spectrum (the 2.4GHz band used by WiFi) is an example of MNOs using multiple different types of spectrum licensing

- OTT voice services such as Skype and WhatsApp run over the Internet data capability of smartphones. In principle, the OTT voice provider (e.g. WhatsApp) cannot manage the quality provided by the mobile Internet connectivity (or WiFi/fixed broadband, if at home).

2.3.5 Increasing use of network function virtualisation (NFV) and software defined networking (SDN)

Fixed and mobile networks, in particular core networks, are both evolving to be more flexible and software-defined. As networking equipment is essentially software, vendors are moving to a model in which the "router" or "switch" or "firewall" is controlled by software and in future will be just software running on commodity infrastructure (e.g. PCs) which could be in different locations

(either spread out across the network[11], or in a central datacentre). This will be a major change involving significant capital expenditure on core networking, and will cause significant changes for the ecosystem of equipment vendors. The major web-scale Internet platforms such as Google and Facebook are a significant part of this movement.

"Network slicing" is a concept related to SDN and NFV and forms a core part of the vision for future mobile networks in the 5G era. Network slices are virtual networks offering different network features (throughput, latency, guarantees) to different customers or services that want them

- Voice may need low throughput, but at a constant rate
- Emergency "blue light" services / PPDR services provided over public networks might need prioritised access to a fraction of the network capacity
- Transport telematics / V2X / CAVs might include some applications with a need for low latency – although it should be noted that 5G is not necessarily essential to achieve this since the industry has specified a direct mode version of LTE which, combined with existing cellular networks, is designed to provide V2X with low latency

Network slicing will be supported by 5G networks (although is yet to be specified in detail) and virtualisation is also likely to be supported by sufficiently advanced 4G networks.

2.3.6 Impact of network technologies and deployment styles on LTIEU

New technologies and deployment styles can increase the quality of mobile services, enabling increased speeds and increased capacity. They can also reduce unit costs, lower the costs of increased coverage, and enable new types of operator to enter the market.

Many of the forthcoming changes to underlying network technologies are (individually) evolutionary in relation to the current mobile market. For example, massive MIMO technologies can be deployed simply to increase the capacity available on existing towers providing wide-area coverage, and tiny Internet-connected base stations ("picocells" and "femtocells") can be used to increase in-building coverage. However, these changes can also be revolutionary:

- For a subset of end users, the high capacity of massive-MIMO-enabled mobile networks might be sufficient to allow them to become or remain mobile-only (including using "fixed wireless" services offered over mobile networks) even in an environment where the majority of end users adopt ultra-high speed fixed services at home.
- Using femtocells allows a new kind of mobile network deployment, the so-called "inside out" network which starts from a femtocell in each end-user's home connected to the Internet; wide area coverage is either rented (using a "national roaming" commercial arrangement) or built on many fewer towers given that the network will not need to build as much capacity for in-building use.

11 "Mobile edge computing" is a related example of putting application processing deep in the network.

Patently however these divergent futures (one with a fixed wireline network connection at home, and one which does not have a fixed wireline connection at home) will not both happen for the same customers.

The Commission should therefore be aware of the possibility that the future developments will not simply be small changes to the current position.

2.4 Wholesale and retail arrangements

2.4.1 Network sharing

Network co-operation is a well-established measure for mobile operators to reduce network-related costs. Conceptually, a range of network elements can be shared. Increasing the depth of sharing offers incremental cost savings relative to a standalone network. Different forms of co-operation models are possible wherein operators can share

- **passive infrastructure**, such as rooftop and tower constructions (passive infrastructure co-operation)
- **active electronics**, such as transmitters, power supplies, amplifiers, radio network controllers (Radio Access Network (RAN) sharing). There are two chief variants, Multiple Operator RAN (MORAN) and Multiple Operator Core Network (MOCN).
- **spectrum**, as well as active electronics (a variety of RAN sharing)
- **core network**, including routing and switching equipment, platforms and systems in addition to spectrum and active electronics (national roaming). National roaming-based co-operation means that one operator relies on the host operator's network infrastructure and existing coverage for a certain, defined footprint. It is often used on a temporary basis.

Depending on its objectives and characteristics, an operator can choose from different network co-operation models and it is not limited to one of them. In fact, different co-operation models can be used for specific services, technologies and frequencies and these can be combined.

Each sharing model has different cost-saving implications for the operators: deeper sharing saves more costs (e.g. if the total capacity needed is less than half a base station each, then one base station can serve both networks' customers). In addition, the deeper the co-operation in terms of asset sharing, the more the operators rely on each other in terms of network infrastructure and functionality.

There are potentially competition related concerns in different forms of sharing, largely because the operators' network coverage, capabilities, and unit costs can become more correlated, reducing the dynamic efficiency benefits gained from having multiple independent infrastructures. Some countries have also worried about the ability of other non-sharing operators to compete. However, in most cases, technical, coverage, retail and wholesale service differentiation remains possible, retaining the benefits of the lower costs (which can in turn enable greater coverage). NRAs and competition authorities in other countries have investigated network sharing proposals and inter-operator contracts that ensure the right competitive incentives are retained.

Some types of sharing such as spectrum pooling can also provide higher peak speeds than independent networks and (subject to competitive safeguards) could be interesting as an option to increase the peak mobile broadband speeds supportable in ultra-rural areas. The option to do this in the "priority deployment zone" (corresponding to the least dense 18% of the population) was provided as part of the 800MHz licences in France.

2.4.2 New types of MVNO agreement

Mobile virtual network operator (MVNO) access is a common feature of mobile markets in other countries. This allows service providers to enter the retail market by re-selling capacity on the network of their host MNO. Such access can be on a variety of commercial terms: either on the basis of some *per-minute* or *per-MB* rate, or *capacity-based* (either a large committed volume or a percentage of the total network capacity over time).

On the per-unit deals, unless these are structured such that unit wholesale prices decrease in line with mobile operator unit costs, then an MVNO with such a wholesale deal will become less and less competitive as network capacity and data demand increases, and network unit costs decrease.

On the other hand, capacity-based arrangements can be for a constant fraction of the capacity (which will increase over time in line with demand) and can also enable the MVNO to compete over a wider range of retail propositions, including very large bundles (which represent a margin risk if the wholesale deal is per-unit).

MVNO access has also been imposed by competition authorities as a remedy in some recent in-market mobile mergers in the EU. These remedies often use capacity-based MVNO arrangements.

2.4.3 New types of player in the market

Once commercial access to national roaming or MVNO is available, this can be combined with new architectures and new technologies to allow new types of operator or new ways for service providers to enter the retail market. One example is the case of Free, a large French fixed ISP that obtained a spectrum licence, used 3G femtocells in its set top boxes to build in-building coverage and a large national roaming deal to carry much of its outdoor traffic while it built out its own base stations to provide coverage. This is an example of so-called "inside out" deployment (see below): the logic is that much mobile phone use is in fact indoors (and data use is often on WiFi).

2.4.4 Impact of wholesale and retail arrangements on LTIEU

New wholesale arrangements and new technologies will support a more dynamic retail market with benefits in terms of product and service innovation as well as competitive pricing.

Making greater use of network sharing would enable lower unit costs and/or additional service coverage at current unit costs. As long as the retail market is competitive, we would expect these lower costs to be passed through to end users.

Network sharing can give rise to competition concerns, but the experience of managing such concerns in Europe shows that at least the majority of the potential benefits of sharing can be obtained without competition being harmed.

2.5 New device technologies

2.5.1 eSIM

The subscriber identity module (SIM) is a physical smart card which is placed in a mobile phone. The SIM is managed by the mobile network operator or the MVNO, if it is a "full" MVNO. In such a model, changing phone and keeping the same operator, tariff, and phone number is relatively easy (you move the SIM from one to the other); moving to another network means changing the SIM.

Changing the SIM is impractical for devices that are deployed in difficult to reach locations (such as many IoT devices) and for certain devices that need to be very small, or water-tight (e.g. connected watches[12]), where an embedded SIM would be preferable. As a result, there are now electronically updatable SIMs being deployed (such as eSIM).

2.5.2 Impact of new device technologies on LTIEU

eSIM may make certain new device types feasible, which may benefit IoT applications in particular. Moving to eSIM may also make it more straightforward for MVNOs to change their host network. As long as eSIM is supported by multiple networks, this ought to make the wholesale market more competitive; in the short term, before network support for eSIM is widespread, it might mean that some devices (those requiring eSIM) are effectively exclusive to a particular mobile network.

2.6 Convergence of fixed and mobile networks and services

2.6.1 Fixed and mobile networks and services will look more similar in the future

As can be seen from much of the discussion above, fixed and mobile networks are becoming more similar.

- The peak speeds and capacity offered by mobile networks are increasing, meaning that there is a subset of end users that may use mobile network services, (including "fixed wireless" services offered over mobile networks, which are already being offered in New Zealand), as a substitute for fixed wireline network services
- The voice, messaging, audio and video services and applications offered over fixed and mobile networks are similar
- The networks themselves are becoming more similar with software-defined core infrastructure, fibre extending from the core to a point close to the end user, and a radio element at the edge of

12 E.g. Apple Watch series 3

the network. In the case of fixed, the radio element is the in-home or in-office WiFi; in the case of mobile is it (say) 4G.

Indeed "mobile" services (voice on smartphones) may be delivered entirely over fixed infrastructure (e.g. via VoWiFi).

2.6.2 Impact of convergence of fixed and mobile networks and services on LTIEU

While wide-area mobile connectivity is of course a singular feature of mobile networks, it is becoming increasingly difficult to draw a line between the retail markets for fixed and mobile services used in the home or office. This could have positive and negative effects on competition and the interests of end-users. The capabilities of the mobile networks may improve the competitive dynamic for "fixed" services especially at lower speeds (particularly in urban and suburban parts of New Zealand where the mobile networks are likely to have high levels of capacity); conversely, if bundled offers of fixed and mobile services become highly attractive, the lack of competitive dynamism of the current mobile market might adversely affect the relatively more competitive fixed retail market.

Again, this means that the Commission may need to consider the wider picture in its review.

2.7 Spectrum bands and licensing

2.7.1 Spectrum and its influence on network coverage and capacity

Coverage

Traditional mobile network deployments often include an initial roll-out phase of a 'primary coverage layer' (providing a reasonable level of 'outdoor' coverage) to a significant part of the population and area of the country at an early stage of network operations.

Low-frequency spectrum (sub-1GHz bands) offers superior spatial propagation characteristics when compared to high-frequency spectrum. This means that coverage can be provided at lower costs (as a smaller number of base stations is required to provide a given level of coverage).

In-building coverage ('indoor' coverage) is typically not as good as that provided in outdoor environments. This can represent a challenge when deploying mobile network infrastructure, especially in urban areas. Again, low frequencies may offer better indoor coverage. As outdoor coverage becomes ubiquitous among operators, providing good in-building coverage plays an increasingly important role in service differentiation, and in attracting and retaining users.

Mobile operators may seek to improve indoor coverage by deploying specialist, localised in-building systems as a complement to the wide-area coverage provided by base stations on towers and

rooftops[13]. These in-building systems include repeaters, small cells (such as those enabled by centralised RAN), and femtocells.

Capacity

The traffic load carried by mobile networks is growing, driven by a combination of growth in the number of users connected, and in increase in the traffic per user (reflecting the capabilities and services supported by high-speed data services). As a result, MNOs have to constantly 'dimension' their network capacity to cope with increasing user traffic volumes in order to maintain the quality of service (QoS) they provide. This involves:

- increasing the density of their network infrastructure (building new sites), and/or
- upgrading mobile sites with additional spectral resources.

For any given technology, mobile network capacity is determined by the number of mobile sites and the total spectrum deployed: to offer a given level of capacity, more spectrum requires fewer radio stations, and *vice versa*, although there are limits to site 'densification' (especially in urban areas where potential locations can be limited) which restrict the opportunities to trade off available spectrum against number of sites.

As higher frequency bands can offer the possibility of obtaining larger quantities of spectrum in aggregate, higher frequencies are often highly suitable for adding additional capacity. Operators therefore often sought a mix of both higher and lower frequency spectrum to allow a cost-effective network deployment. Technologies such as multi-band carrier aggregation (which is part of LTE) allow the seamless use of a combination of different bands, providing for greater peak speeds amongst other benefits.

2.7.2 New bands

The spectrum used for mobile communications is valuable and highly used, and additional spectrum can increase capacity and/or reduce unit costs. Many jurisdictions are working on increasing the quantity of spectrum available in order to improve these services yet further. Over the recent past, UHF spectrum formerly used by analog TV broadcast services (the "800" and "700" bands) has been substantially "re-farmed" for mobile use, although there is limited scope to take yet more from DTT (unless the decision is made to completely shut down terrestrial TV and to use alternative means of distribution such as the UFB network or satellite DTH).

A variety of new spectrum bands have been proposed. The table below outlines the mobile bands which the Radio Spectrum Management group within the Ministry of Business, Innovation and

13 Sometimes called 'macro' network

Employment (MBIE) considers to be the most relevant potential 5G candidate bands for New Zealand, based on an industry workshop[14] in October 2017.

Figure 2.7: Candidate spectrum bands considered for 5G in New Zealand [Source: RSM 5G Workshop, October 2017]

Band	Relevance to 5G
610-698 MHz	Other IMT band which could be used for 5G
700/850/900/1800/ 2100/2300/2600 MHz	Existing mobile spectrum may be exploited in combination with 3300-3800 MHz
1427-1518 MHz	Other IMT band which could be used for 5G
3300-3800MHz	Main band internationally being considered for early deployment of 5G
24.25–27.5GHz	One of the main bands being considered internationally for early deployment of 5G
31.8-33.4GHz	Other bands considered in WRC -19 AI 1.13 for the future development of IMT
37-40.5GHz	
40.5-42.5GHz	
42.5-43.5GHz	
45.5-47GHz	
47-47.2GHz	
47.2-50.2GHz	
50.4-52.6GHz	
66-76GHz	
81-86GHz	

The higher frequency bands (millimetre-wave) offer the prospect of very high peak speeds – potentially Gbit/s capacity - but are likely to have a very low range and may require a line-of-sight to the base station.

2.7.3 New types of licensing such as shared spectrum access

The spectrum used for mobile communications systems uses a variety of different models of access to spectrum.

- National or regional exclusivity: Licensed spectrum, where one MNO will be assigned the exclusive rights to use certain frequency bands
- Free-for-all: Unlicensed spectrum, used by short range wireless LAN services such as WiFi for in-building use and for personal area network services such as Bluetooth (e.g. 2.4GHz, also used inside microwave ovens). There is no coordination; you have to accept interference, but in exchange you gain a great deal of freedom and flexibility. Some new technologies such as LTE-U, LAA and MulteFire are also targeted at such bands.

[14] https://www.rsm.govt.nz/projects-auctions/pdf-and-documents-library/current-projects/spectrum-workshop-slides.pdf. The presentation closes by stating that next steps include formal public consultation and release of a 5G strategy document.

In between these extremes there exists a continuum of ways in which the spectrum could be subject to some managed form of sharing with different rights and responsibilities. This is of particular interest because some of the candidate bands cannot be cleared of existing users; this may still leave a great deal of capacity in so-called "white spaces". For example, maritime radar systems may not prevent usage away from the sea and some fixed satellite services need protection only near specific ground stations. This kind of shared use of a band can require innovation in the form of the licensing, as well as technical measures to prevent interference with the existing user's services (such as databases of the geographical locations of the other users).

One such model is called "shared spectrum access". Citizens Broadband Radio Service (CBRS) is an example that is currently being implemented. This will allow sharing of the 3.5GHz band in the US; "grandfathered" incumbent users include maritime radar, broadband FWA, and certain fixed satellite services. It uses a Spectrum Access System to protect incumbent users and an environmental sensing capability (a network of sensors informing the spectrum management function) to avoid interference. The intention is to allow a great deal of innovation in the band that may include (for example) private LTE networks for enterprise sites.

2.7.4 Impact of changes in spectrum bands and licensing on LTIEU

Use of more spectrum for mobile communications services will allow higher speed services and may also allow lower unit costs.

Use of new types of licensing including shared spectrum may increase the variety of services by allowing new types of service providers and/or increase the capacity of services. One such possibility is to provide better or more seamless in-building coverage.

The importance of exclusive ownership of large blocks of spectrum in specific bands may however be changing, as new forms of mobile network architecture (see above) and new forms of cooperation between service providers and network operators (e.g. national roaming) allow new forms of operator. If you can rent access to the wide-area coverage network, then you can be an MNO only with your own in-building coverage (e.g. using high frequency picocells).

This shows that putting new spectrum bands, new architectures, and new commercial arrangements together can in combination have a larger impact than would be expected.

3 Summary

We recommend that the Commission considers a wide scope within its review. This will allow the review to encompass the wide variety of possible future market changes and the number of different ways in which the decisions of the Commerce Commission (and the NZ Government more widely) can and will affect the development of the communications industry.

The long-term interests of end users (LTIEU) can be better served in the following ways:

- The dynamic efficiency benefits of competition are not yet felt as strongly as they might be in the mobile market in New Zealand: a more dynamic retail market would bring benefits in terms of product and service innovation as well as competitive pricing. This can be aided by more retail players making use of new wholesale arrangements and new technologies.
- Lower unit costs and/or additional service coverage at current unit costs can in future be delivered by: making greater use of network sharing; using additional spectrum (some of which may be dynamically shared with other uses); making more efficient use of the spectrum already available; and through innovations in devices and network technology.
- These innovations may extend to new styles of network deployment and new wholesale models, each of which may enable or support additional types of retail player (improving dynamic efficiency), as well as enabling new types of services. These may include bundles of services bringing together fixed and mobile elements, and services designed for specific classes of users, for example: supporting the emergency services; connected and autonomous vehicles or the Internet of Things.

Many of the forthcoming changes to underlying network technologies are (individually) evolutionary in relation to the current mobile market. However, these changes can also be revolutionary, allowing new architectures, new types of service provider, new business models, and new services. The Commission should therefore take care to consider the potential wider impacts of specific changes on the entire market, including the combined effect of technological, commercial, and network architecture changes rather than starting from a position that believes the future will be very much like the past.

Annex A Glossary

Active infrastructure: electronics. Includes base station electronics (BTS/Node B), BSC/RNC, and the transmission to the backhaul and core network

Antenna: a device usually mounted on tower/masts that radiates or captures radio frequency electromagnetic waves

Backhaul: Network between the mobile base station (Node B) and core network (e.g. to aggregation node)

BBU (Baseband Unit): a unit that processes the baseband signal in architectures using remote radio units. This is placed in the shelter room and connected with the RRU via an optical fibre

BSC (Base Station Controller) / RNC (Radio network controller): equipment that controls a number of BTSs / Node B and generally located more centrally (e.g. at a regional aggregation point or switch location).

BTS (Base Transceiver Station) / Node B: the transmitting and receiving electronics and antennas at the edge of the mobile network, typically with the antenna mounted on a large metal mast or a smaller structure mounted on an existing building

CA: carrier aggregation. The ability to join together the capacity provided by non-contiguous blocks of spectrum into a larger capacity. Supported by LTE but not 2G or 3G standards.

CAV: Connected and autonomous vehicle, such as a self-driving car with a network connection.

CBRS: Citizens Broadband Radio Service. A proposed US system using shared access to spectrum in the 3.5GHz band.

CDMA (Code-Division Multiple Access): an alternative method of sharing spectrum over time and frequencies mainly used in 3G technologies; also shorthand for a particular 2G standard digital cellular phone technology (IS-95)

eSIM: An embedded SIM, programmable over-the-air by the MNO

Femtocell: tiny Internet-connected mobile base station

Fronthaul: Network between the remote radio unit and the baseband unit

GPRS (General Packet Radio Service): a packet data service – originally an upgrade to the 2G GSM service

GSM: A 2G mobile network standard.

HSPA: High speed packet access – the data speed upgrade to 3G networks.

HHI (Herfindahl–Hirschman Index): An indicator of market concentration. The sum of the squares of the competitors' market shares.

IoT: Internet of things

LAN: Local area network (usually internal to a building) e.g. domestic WiFi

LTE: Long Term Evolution. A 4G standard.

Massive MIMO: MIMO using very large numbers of antenna elements.

MIMO: Multiple input multiple output – a technology which increases the throughput possible in a given amount of radio spectrum by using multiple antennas both to transmit and receive, in order to use multiple independent transmission paths between the sender and receiver.

MNO: Mobile network operator

Mobile broadband: Browser based high speed access to the Internet or web applications using a mobile device, such as a smartphone, connected to a wireless mobile network

MSC (Mobile services switching centre): equipment that co-ordinates the setting up of calls to and from mobile phones in the mobile operator's network

MTAS (Mobile termination access service): a wholesale call termination service bought by a telecommunications network operator when a subscriber makes a voice call to a mobile network operator

MulteFire: A standard that extends LTE to work in shared and unlicensed spectrum

MVNO (Mobile virtual network operator): a telecommunication purchasing wholesale capacity on the network of a mobile operator to retail mobile services. A "full" MVNO has its own network switch and manages its own SIMs.

NFV: Network function virtualisation. Replacing dedicated network equipment performing a network function (such as a router or a firewall) with software running on one or more commodity computing platforms.

Passive infrastructure: In relation to mobile infrastructure, everything other than the active electronics: e.g. tower/mast, feeder cable, antenna, shelter etc present at the site

QoS: Quality of Service. Can in practice refer to a variety of metrics of quality including coverage, peak speed, guaranteed throughput, time to repair. Higher QoS is sometimes provided using prioritisation.

RAN: Radio access network.

Retail: refers to a service sold to an end-user

RRU (Remote Radio Unit): is a channel processing equipment which communicate with BBU typically via a physical communication link

SDN: Software defined network. The ability to reconfigure the network in software. Related to the concept of Network Function Virtualisation.

SIM: Subscriber Identity Module. A physical smart card which is placed in a mobile phone or tablet; the mobile phone number and tariff plan is associated with this card rather than the device itself.

UMTS: Universal Mobile Telecommunications System. A 3G mobile standard.

VoLTE: Voice over LTE

VoWiFi: Voice over WiFi

V2X: Vehicle-to-any communications

Wholesale: refers to a service sold to another telecommunications operator or company

2G: second generation of mobile telephony systems using digital encoding to support voice, with limited data communications. One such standard is GSM.

3G: third generation of mobile telephony systems, providing data speeds generally higher than 2G and supporting multimedia applications such as video and Internet access. One such standard is UMTS.

4G: fourth generation of mobile telephony systems. Features include higher download/upload speeds as compared to 3G and more efficient spectrum usage. One such standard is LTE.