Legacy mobile network rationalisation

Experiences of 2G and 3G migrations in Asia-Pacific

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NETWORK STRATEGIES
• Telecommunications Strategy •

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Network Strategies and WPC acknowledge the significant contribution of various officials from the GSMA, national regulatory agencies, mobile network operators and equipment vendors in the preparation of this report.

Contents

1. Executive summary

The pioneers in legacy network rationalisation are found in the Asia-Pacific region. Here operators started rationalising 2G services as early as 2008 to 2012, with many others following in more recent years. Drawing on the experience of six case study markets from the Asia-Pacific region, this report explores the most suitable market, regulatory and commercial conditions for achieving a smooth and successful switch-off. The case study markets differ in terms of characteristics of the mobile market, extent of regulator involvement and approaches to spectrum allocation and management. As such, the impact of each of the key drivers on the decisions varied from market to market, with spectrum related issues being the most prominent driver.

Decisions to sunset 2G services and, more recently, 3G services are based on a wide range of considerations. Mobile network operators (MNOs) seek to rationalise legacy network technologies as more spectrally efficient technologies become available and the nature of consumer demand changes.

MNOs: key drivers and benefits

- Refarm spectrum and deploy most cost-effective technology;
- Reduce operational costs;
- Meet increased demand for mobile broadband and data intensive applications from smart devices;
- Potential market and competitive effects for the first mover;
- Meet Government expectations of deploying the latest innovative mobile technology.

Comprehensive strategies require an understanding of risks for both operator and consumer.

MNOs: key risks

- Customer churn, particularly when operators do not switch off at the same time
- Uncertain demand for new services and capacity
- The cost of migrating M2M connections
- Possible changes in coverage, particularly if the new technology (such as VoLTE) does not provide the same coverage as the replaced legacy technology on the same band, or it operates in a frequency band that does not provide adequate indoor coverage without further network investment
- Potential brand damage if some customers are left without coverage, are forced to upgrade handsets or large numbers of M2M connections are disconnected for business customers.

Decisions are invariably driven by operators, with differing degrees of involvement by regulatory authorities. The latter is, for example, needed if spectrum allocations are not technology neutral. However, consumer protection is typically the paramount concern of regulators. Thus, a smooth process depends on careful planning of a transitional period, obtaining regulatory approval where necessary, and above all ensuring effective customer engagement. Based on the experience of the case study markets best practice approaches encompass several key characteristics:

- A transitional period of around three years, with preparations commencing earlier than formal public announcements;
- Coverage of any new technology that matches what was previously offered;
- A reasonable formal notice period, given specific market circumstances and potential obligations;
- A well-designed campaign involving direct targeting of affected customers, possibly assisted by the regulator;
- Upgrade incentives for customers, including comparably priced plans, and handset recycling initiatives as part of any 2G or 3G switch-off; and
- A quality of service that is maintained during and after the transition.

Delays in scheduling 2G network rationalisation projects may be caused by the size of operators' customer bases for 2G on M2M and IoT applications, particularly where long term support agreements exist. Given that technical options exist for migrating such applications, the cessation decision for 2G and 3G technologies is an economic one. Key factors in the decision include the size and type of subscriber base, current and forecast revenues, and the cost of substitution.

For regulators, the implications of a 2G or 3G switch-off should be considered in relation to key spectrum management issues. These include the need for minimum spectrum allocations suitable for utilising newer technologies and the possibility that lengthy renewal of 2G spectrum allocations may result in unused spectrum, particularly in sub-1 GHz bands.

2. Introduction

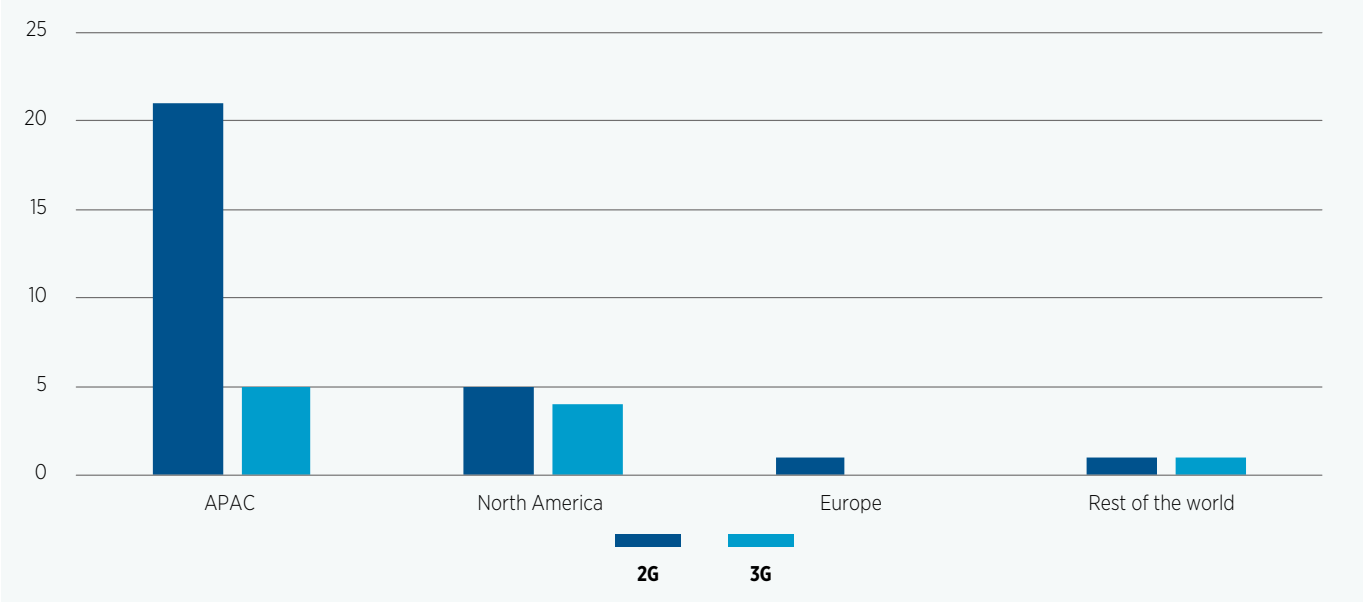
With the smartphone revolution, and the rapid growth in wireless data services, operators worldwide are exploring opportunities to reduce costs, or to re-use 2G/3G spectrum for the more cost efficient 4G and 5G technologies, through shutting down networks using the older legacy technologies. However, operators are employing differing decommissioning strategies and timetables, influenced by characteristics of the local markets.

APAC (Asia-Pacific) markets are leading the way (Exhibit 2.1). In many APAC markets, such as Singapore, New Zealand and Australia, operators have already decommissioned their 2G networks. Phasing out 2G networks is the preferred option in the APAC region and North America. However, due to the significant size of the markets for 2G based M2M and IoT applications, many European mobile operators are planning to retire 3G services before 2G.

EXHIBIT 2.1

Source: Network Strategies

2G AND 3G SWITCH-OFF AROUND THE WORLD



In many cases, including in Australia and New Zealand, shutdown of 2G and 3G networks is being driven entirely by operators. However, in some Asian markets the switch-off has been encouraged by the regulator, and there has been greater regulatory engagement in the process. There are a number of considerations that should be explored in any development of strategies for the shutdown of legacy networks. These may include coverage, customer migration and affordability, local regulations, spectrum, and may even address options for retaining a shared legacy network or the retention of 2G utilising only minimum spectrum.

The accelerated pace of 5G deployments in the APAC region is resulting in more mobile operators considering the future of their 2G and 3G networks.

Study objectives

This report aims at identifying the most suitable market, regulatory and commercial conditions for switching off 2G and 3G networks in APAC markets. In particular, it examines:

- Likely drivers for legacy 2G and 3G network shutdown;
- The necessary steps to initiate a network switch-off;
- Conflicts that might arise from suspending dependent services, such as M2M and IoT, and options to mitigate these conflicts;
- Conditions determining the sequence of 2G and 3G switch-off;
- Advantages of an operator led switch-off and incentives the regulator may provide to facilitate the operator led switch-off; and
- Whether a set of conditions needs to be met in order to develop a best practice approach.

3. Key drivers and barriers

3.1 Overview

Since the introduction of 2G in the early 1990s, it has been the prevalent mobile networking technology in terms of coverage in most markets. 2G was mainly specified for voice communications and has limited data capabilities. In response to the growing demand for mobile data, 3G networks were introduced commercially in the early 2000s. Subsequently, as the rate of growth of demand for mobile data increased exponentially, 4G and 5G technologies offered significantly higher spectral efficiency and higher capacity than predecessor technologies.

As 3G and 4G penetration rates reached those of 2G, a number of markets decommissioned 2G, and in some cases 3G networks.

As of mid-2019, more than 20 2G networks and at least five 3G networks have been decommissioned globally[1]. Many other operators have already announced dates. The rapid growth of 5G deployments is also likely to mean that many mobile operators will announce the timetable for 2G or 3G switch-offs in 2020 as they rationalise the costs of deploying 2G, 3G, 4G and 5G networks. Notably, the majority of these switch-offs are in the APAC region (Exhibit 3.1). Despite being technologically obsolete, 2G and 3G network rationalisation decisions are based on a wide range of considerations. These include the potential economic and societal impacts, commercial drivers, spectrum management and refarming, regulatory obligations and service migration challenges.

EXHIBIT 3.1

Source: operators, TeleGeography, authors

SCHEDULE FOR 2G AND 3G NETWORK SHUTDOWNS FOR A SAMPLE OF APAC OPERATORS

Market	Operator	2G technology	2G shutdown	3G technology	3G shutdown
Australia	Telstra	GSM	December 2016	UMTS	June 2024
	Optus	GSM	August 2017	UMTS	-
	Vodafone	GSM	June 2018	UMTS	-
India	Reliance Com	GSM	November 2017	UMTS	November 2017
	Bharti Airtel	-	-	UMTS	March 2020
Japan	KDDI	CDMA	March 2008	CDMA2000	March 2022
	Softbank	PDC	March 2010	UMTS	June 2024
	DOCOMO	PDC	March 2012	UMTS	March 2026
Macau, SAR	Hutchison	GSM	June 2015		
	SmarTone	GSM	June 2015		
	CTM	GSM	June 2015		
New Zealand	Spark	CDMA	July 2012	UMTS	-
	2 degrees	GSM	March 2018	UMTS	-
	Vodafone	GSM	2025	UMTS	-
Singapore	SingTel	GSM	April 2017	UMTS	2025+
	M1	GSM	April 2017	UMTS	2025+
	StarHub	GSM	April 2017	UMTS	2025+
South Korea	KT	CDMA	January 2012	UMTS	-
	LG U+	CDMA	July 2021	CDMA2000	-
Thailand	CAT	CDMA	April 2013	-	-

1. Real Wireless (2019), The potential Impact of Switching Off 2G in the UK, report for the UK Spectrum Policy Forum,October 2019.

3.2 Market drivers

There are several factors driving mobile network operators to rationalise legacy network technologies, with the main drivers being:

- More efficient use of spectrum;
- Spectrum harmonisation;
- Spectrum licence expiry;
- Reducing operational costs; and
- Meeting increasing demand for mobile broadband and data intensive applications.

Spectral efficiency

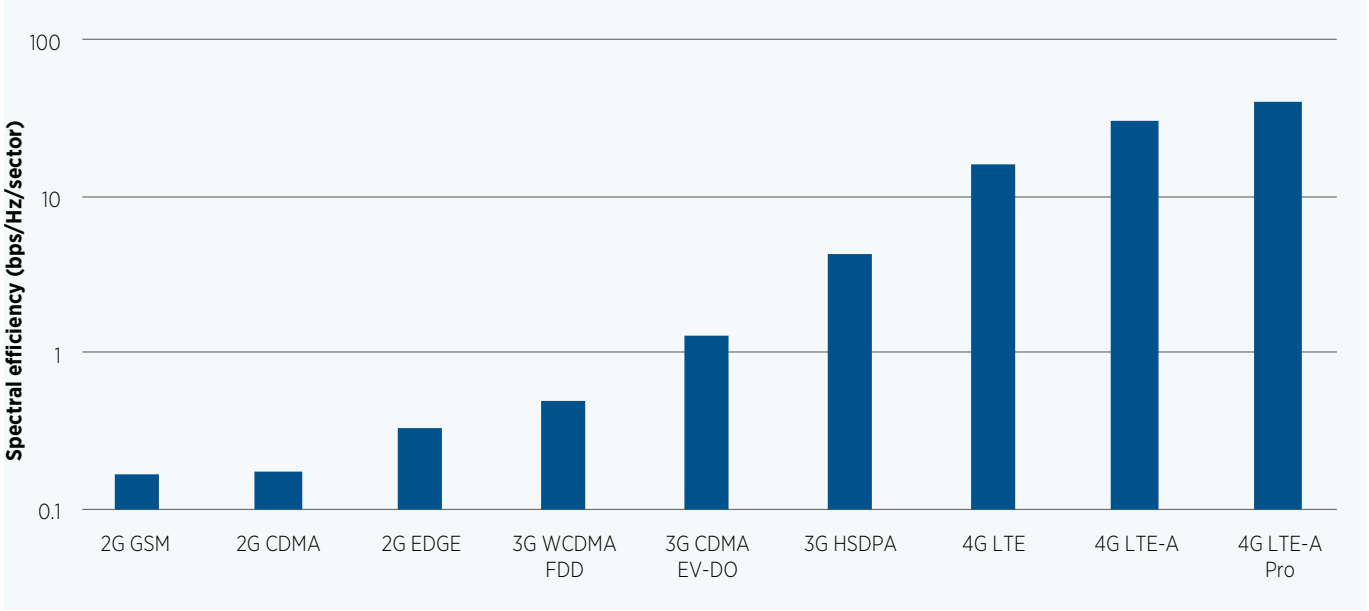
Refarming spectrum for more efficient technologies is an objective that is generally shared amongst both regulators and operators. While regulators seek to maximise the societal impact of mobile communications with optimal use of spectrum, operators seek to maximise revenue by accommodating more traffic per licensed spectrum band. The peak spectral efficiency of mobile technologies, namely the amount of traffic carried in a cell site, has increased more than 200 times since the introduction of GSM in 1991 (Exhibit 3.2)[2].

Most 2G systems use the 850, 900, 1,800 or 1,900 MHz frequency bands. The sub-1 GHz bands, in particular, are very valuable due to their better propagation characteristics, delivering greater coverage and in-building penetration. As spectrum below 2 GHz is scarce, the reuse of these frequency bands for new and more efficient technologies is essential in many cases. Spectrum reuse has been the main driver for the 2G network rationalisation projects in many APAC markets, including Australia, Singapore, South Korea and China. This is particulary critical for operators with small spectrum holdings. Furthermore, packet-switched technologies such as 4G and 5G have greater call handling capacity than the circuit-switched 2G and 3G systems, which adds to the capacity improvements gained by the more advanced radio access technologies.

EXHIBIT 3.2

Source: Network Strategies

THE EVOLUTION OF MAXIMUM ACHIEVABLE SPECTRAL EFFICIENCY OF MOBILE TECHNOLOGIES FROM GSM TO 4G LTE-A PRO



2. Peak spectral efficiency is only achieved in ideal conditions. In typical propagation conditions, the spectral efficiency has increased about 30 times.

Spectrum harmonisation

Spectrum harmonisation refers to the consisent allocation of frequency bands across countries. This is necessary for reducing interference across borders, enabling global roaming, interoperability and to reap the benefits of economies of scale from equipment vendors. Spectrum harmonisation was early on a key driver for retirement of 2G networks in Japan between 2008-2012. The reason: most Japanese 2G systems were based on the Personal Digital Cellular (PDC) standards that were exclusively used in Japan.

Spectrum expiry

The expiry of spectrum rights can be an important factor in triggering the decommissioning of a legacy network, if other market conditions are met. This has played a role in Singapore. In Singapore, the spectrum rights for 2G expired at the same time for all three operators. Given that 2G demand was declining and the adoption of 3G and 4G services was high, the operators took advantage of the licence expiry to approach the regulator for a simultaneous 2G switch-off.

Reducing operational costs

As running multiple generations of mobile networks simultaneously is economically inefficient, operators tend to decommission the redundant legacy networks to reduce operational costs[3]. Cost reductions emanate from:

- Simplifying network management operations and RF planning;
- Avoiding costly maintenance of ageing network equipment, including equipment spares;
- Eliminating ongoing costs of software licences;
- Reducing lease cost of tower space for multiple antennas; and
- Reducing energy consumption of the network.

In mobile networks the main consumer of power is the base stations. Nevertheless, advances in hardware, reduced equipment size, advanced radio interface technologies and virtualisation of core network functions have improved network power consumption efficiency[4,5]. In a recent press release, Vodafone New Zealand predicted that network upgrades will reduce power costs by 10% in the coming years[6]. Improved power efficiency has additional benefits in terms of reducing air-conditioning and battery backup capacity which in turn reduces the equipment footprint, and hence, co-location costs. Obviously, there are environmental benefits from such an approach.

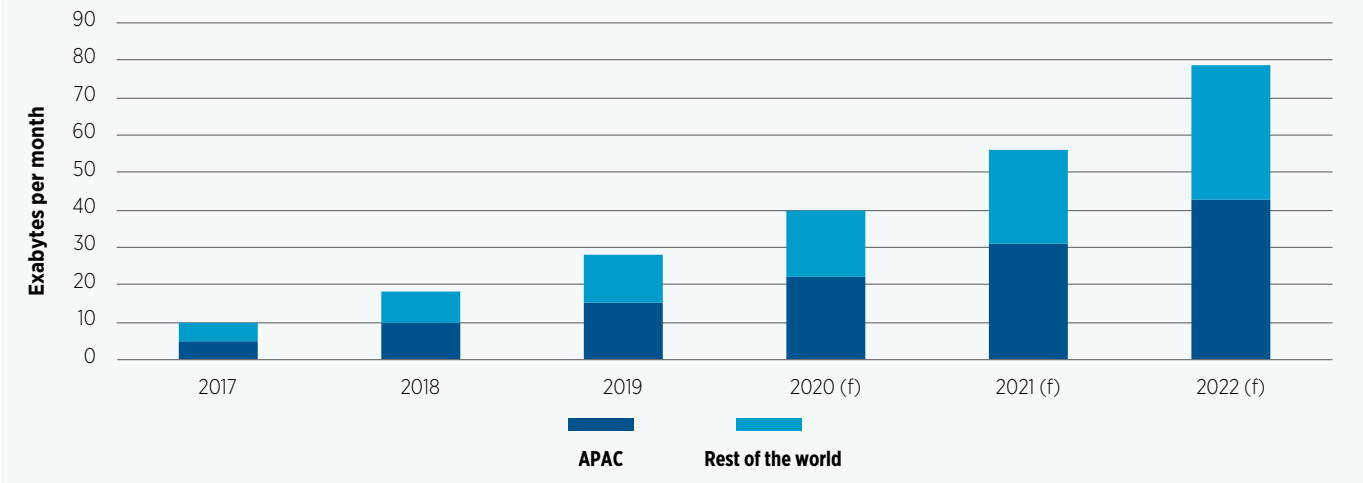
The rise of data

Since the emergence of 3G networks mobile networks have become increasingly data-centric. Accordingly, subscribers enjoy greater functionality and higher connection speeds. This development has also diversified revenue streams for mobile operators, with revenues coming largely from subscriptions and pre-paid packages of combined voice and data bundles. The need to focus on high value services enabled by data, alongside cost optimisation, was the main driver for the first 2G network switch-off in New Zealand. Mobile data traffic grew an estimated 86% in the APAC region in 2017[7]. By 2022, APAC is expected to account for 56% of global mobile traffic, reaching about 43 Exabytes per month (Exhibit 3.3)[8].

EXHIBIT 3.3

Source: Cisco

GLOBAL MOBILE DATA TRAFFIC FORECAST



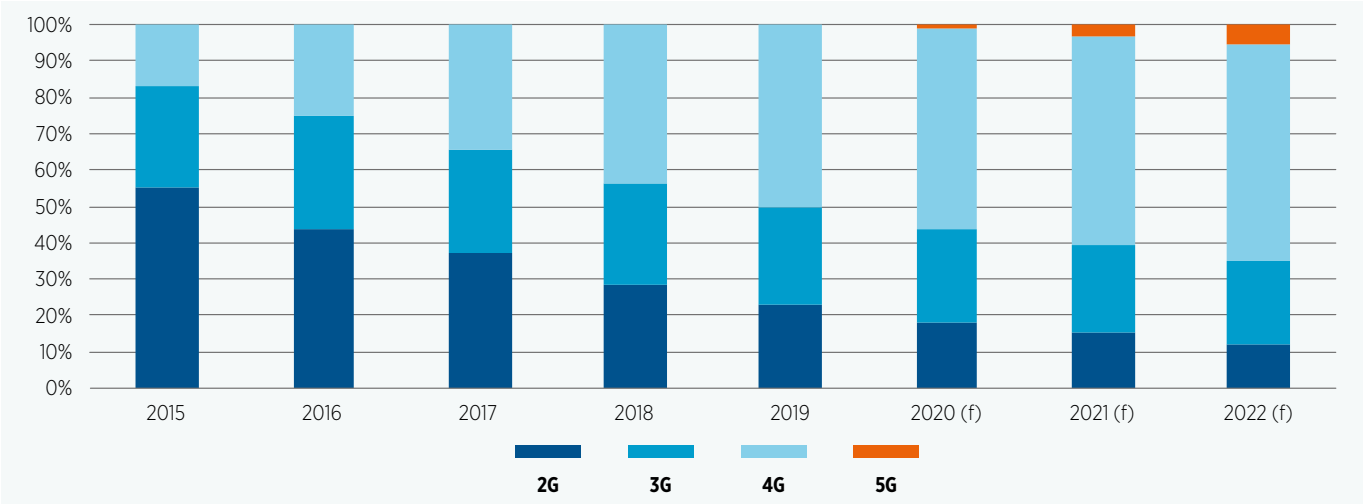
3. Some new base stations and platforms do support multiple mobile generations. However, this is only cost effective for new network deployments.
4. Margot Deruyck et al. (2012), Reducing Power Consumption in Wireless Access Networks: Overview and Recommendation', Progress in Electromagnetics Research, Vol. 132, pp.255-274.
5. Rashid Mijumbi et al. (2015), On the Energy Efficiency Prospects of Network Function Virtualization, Cornell University arXiv eprints, December 2015.
6. Vodafone (2019). Vodafone predicts 10% power savings with network upgrade program. Press release, November 2019. Available at https://news.vodafone.co.nz/article/vodafone-predicts-10-power-savings-network-upgrade-program
7. Cisco (2019). Cisco Visual Networking Index: Global Mobile Data Traffic: Forecast Update, 2017-2022, February 2019.
8. Cisco (2019). Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2017-2022, February 2019.

To meet growing demand for more bandwidth and mobile applications, 4G deployments have increased steadily worldwide. On a global scale, the number of 4G connections has already surpassed both 2G and 3G connections in 2017. From 2015-2019, 4G connections more than doubled in the APAC region, reaching about 50% of total mobile connections[9]. At the same time, the proportion of 2G connections has seen a sharp decline, accounting for 23% of connections as at 2019 (Exhibit 3.4). Most 2G networks are likely to be fully amortised. However, given the continued decline in connections and traffic, it is unlikely that the generated revenues could justify the operational cost.

EXHIBIT 3.4

Source: GSMA

APAC MOBILE CONNECTIONS FORECAST BY TECHNOLOGY

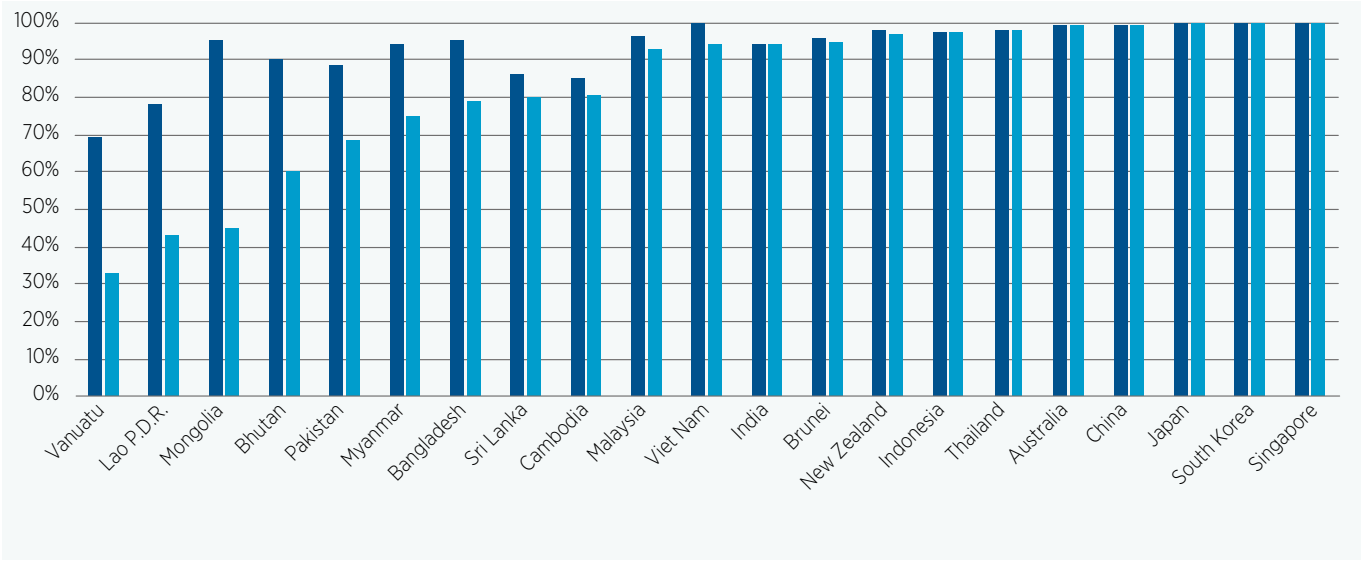


In contrast to 2G, the global share of 3G has been relatively stagnant from 2015 to 2019. In many APAC markets, particularly less developed or large area markets, 3G still has a much larger population coverage than 4G (Exhibit 3.5). Even in APAC markets where both 3G and 4G have virtually ubiquitous coverage, 3G networks are still in operation for a variety of reasons. In many cases 3G deployments (including HSPA+) have not amortised yet and still meet a sizable market demand. Operators still provide substantial broadband capacity over 3G using spectrum that otherwise might not be so easily re-allocated to 4G.

EXHIBIT 3.5

Source: ITU

PERCENTAGE OF POPULATION COVERED BY 3G AND 4G NETWORKS IN A SELECTED NUMBER OF APAC MARKETS, 2018



9. GSMA (2019). The Global Mobile Economy, 2019.

3.3 Barriers

3.3.1 VoLTE

One reason for maintaining legacy networks is that not all 4G operators have launched VoLTE capability or have not achieved VoLTE coverage matching that of 2G or 3G. Many early 4G deployments did not deploy VoLTE technology when the network was launched. As such, a 2G or 3G network is still needed to handle voice calls. While data is carried over the LTE network, voice calls fall back to circuit-switched 3G or 2G networks, which is referred to as circuit-switched fallback (CSFB). Additionally, CSFB is used when calling a device connected to 2G or 3G network. Ongoing calls originating on VoLTE will also need to be handed over to 2G/3G when mobile users move out of VoLTE coverage, which is enabled by the Single Radio Voice Call Continuity protocol (SRVCC).

As at August 2019, the Global Mobile Suppliers Association (GSA) estimated that 262 MNOs had launched or were investing in VoLTE, representing approximately 26% of operators worldwide[10]. However, the number of VoLTE launches has been steadily increasing since 2016.

The implementation of VoLTE can be associated with many technical challenges. Essentially, VoLTE is a data service. However, in contrast to typical best-effort IP data traffic that can be reduced if the link is of low quality, VoLTE requires a guaranteed data rate. The network responds to these situations by allocating more capacity resources to the VoLTE call, which may cause the overall quality of the network to degrade. As such, LTE radio access networks (RAN) may need to be re-optimised to provide the required VoLTE service guarantees. Further complications arise if the LTE coverage is not continuous. This may lead to excessive handovers to 2G/3G, degraded voice service and potentially to dropped calls. Depending on the existing infrastructure, VoLTE may require substantial investment in the core network, including an IP multimedia subsystem (IMS). Many functionalities in the core have to undergo extensive optimisation and trials before service launch. Given the declining voice revenues and the associated challenges and investments, many operators do not see the benefit of an early VoLTE deployment.

3.3.2 Smartphone penetration

On the demand side, the penetration of smartphones is an important factor, particularly when deciding the future of 3G technology. While smartphone affordability may not be a major concern in high-income APAC markets such as Singapore and Australia, it still does affect some customer segments. Many budget smartphones still offered in the market today only support 3G, or 4G data without VoLTE. These are either purchased for affordability reasons or by subscribers seeking less functionality, such as elderly people. Just like the number of networks, device support for VoLTE is becoming increasingly common.

3.3.3 Dependent services

A key consideration when disconnecting legacy technologies is identifying feasible alternatives for dependent services. These mainly include:

- Voice and SMS services;
- Machine-to-machine connections;
- Dedicated mobile broadband; and
- Fixed wireless broadband.

Voice and SMS

In many markets, including APAC markets with high 4G population coverage, there may still be a proportion of voice traffic that is only handled by 2G or 3G networks due to:

- Customer segments that use 2G and 3G handsets; and
- Absence of 4G VoLTE coverage.

While the APAC case studies in this report have almost ubiquitous 4G population coverage, the 4G landmass coverage is often less than that of 2G and 3G. In New Zealand, for example, 4G covers about 39% of the land area, compared to 50% for 3G, which has better coverage in rural and remote areas. In contrast, in a market like Indonesia,4G service coverage is now approaching the coverage of 2G services and is already considerably larger than 3G coverage[11]. Roaming visitors with 2G or 3G handsets may also require legacy network technologies. In some markets, such visitors may generate significant voice traffic, although this should decrease as worldwide demand for legacy technologies declines. However, the combined traffic of roaming and resident visitors using 2G and 3G only handsets may still be significant for many operators.

10. Global Mobile Suppliers Association (2019). VoLTE and ViLTE: Global Market Update. GSA, August 2019.
11. From the Direktorat Jenederal Sumber Daya Perangkat Pos dan Informatika (SDPPI), the Indonesian spectrum regulator 2G coverage in Indonesia is 99.19 percent of population versus, 96.3 percent for 3G and 97.59 percent for 4G services. Source: SDPPI, Ditjen, Q2-2019

Machine-to-machine communications (M2M)

M2M devices are application-specific devices that are built for specific services such as truck fleet management, smart metering, medical emergency or intruder alarm monitoring. These devices communicate with other devices, databases and servers, using the mobile network and are usually embedded within machines and instruments. Ideally, their lifetime is as long as that of the machines to which they are attached. As such, longevity and reliability are essential for M2M services, with contracts with mobile operators lasting for up to 15 years.

M2M services over 2G networks typically use GPRS or EDGE protocols on GSM or 1×RTT on CDMA networks. These protocols provide low data rates up to 236.8kbps. 2G M2M modules are simple and low cost and are typically used by M2M applications that transmit relatively low data volumes. 3G provides M2M services using the High Speed Packet Access (HSPA) or Evolution Data Optimized (EV-DO) standards. These standards were specified for mobile broadband and can provide peak data in excess of 28Mbps for HSPA and 3Mbps for EV-DO. As such, their potential capacity exceeds the requirements of most M2M applications.

As an alternative to 2G/3G M2M, 4G offers two data networking technologies, Narrowband Internet of Things (NB-IoT) and LTE Machine Type Communication (LTE-M). NB-IoT is intended for narrow band (250 kbps) low power data applications and does not support voice communications. NB-IoT based on 3GPP realese 13 does not support hand-off between cell towers while the device is connected. As such, it is better suited for fixed devices. However, later releases have introduced enhancements for device mobility. Further enhancements are expected in the coming releases[12]. LTE-M (also known as Cat-M1) provides considerably higher bandwidth (1Mbps), supports voice and full mobility.

According to the GSMA, 127 mobile operators worldwide have deployed at least NB-IoT or LTE-M as at January 2020, including in the six APAC case study markets in this report[13]. The majority of these deployments took place in 2017 and 2018 (Exhibit 3.6). Other APAC markets with NB-IoT and LTE-M networks include India, China, Sri Lanka, Thailand, Bangladesh, Vietnam, Indonesia and Malaysia. The coverage of some of these deployments is unclear. However, operators typically extend NB-IoT/LTE-M deployment to cover all the 4G footprint, particularly where 700 MHz spectrum is available.

EXHIBIT 3.6

Source: operators

NB-IOT AND LTE-M DEPLOYMENTS IN APAC MARKETS IN THIS REPORT

Market	Technology	Operator	Year deployed
Australia	NB-IoT	Telstra	2018
	NB-IoT	Vodafone	2017
	LTE-M	Telstra	2017
Japan	NB-IoT	Softbank	2018
	LTE-M	KDDI	2018
	LTE-M	Softbank	2018
	LTE-M	DOCOMO	2018
	NB-IoT	DOCOMO	2019
Korea	NB-IoT	KT	2017
	NB-IoT	LGU+	2017
	LTE-M	KT	2016
New Zealand	NB-IoT	Vodafone	2018
	LTE-M	Vodafone	2018
	LTE-M	Spark	2018
Singapore	NB-IoT	Singtel	2017
	NB-IoT	M1	2017
	NB-IoT	StarHub	2017
	LTE-M	Singtel	2017

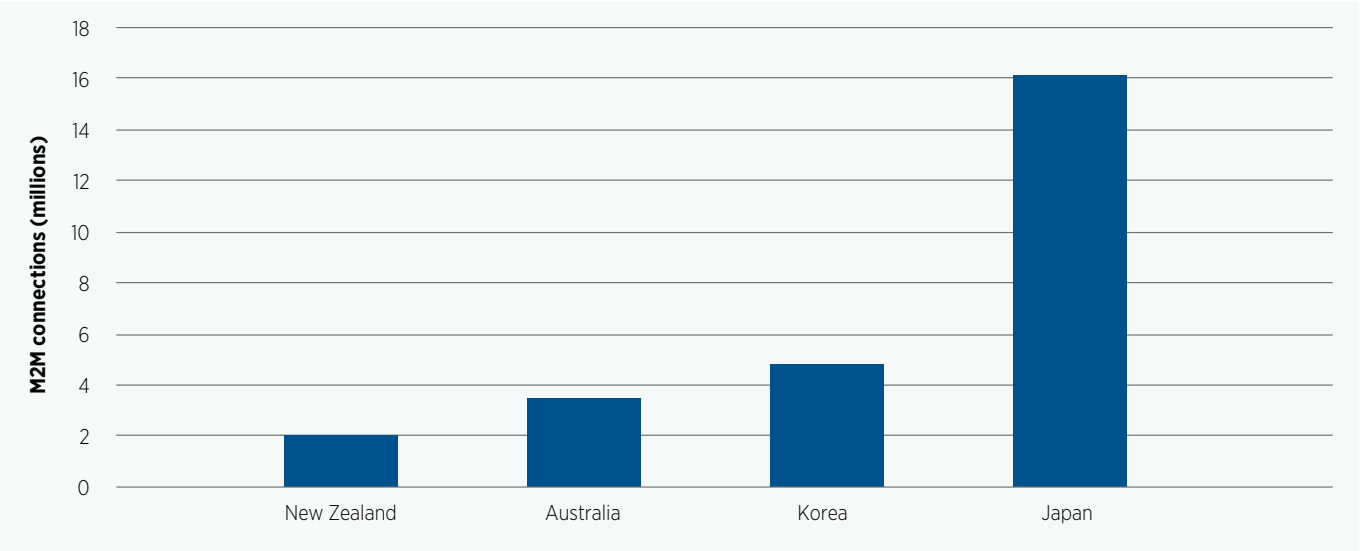
12. C. B. Mwakwata, H. Malik, M. M. Alam, Y. LE Moullec, S. Parand and S. Mumtaz (2019). Narrowband Internet of Things (NB-IoT): From Physical (PHY) and Media Access Control (MAC) Layers Perspectives. Sensors, Vol. 19, p.2613.
13. GSMA (2020). Mobile IoT Commercial Launches. Available at https://www.gsma.com/iot/mobile-iot-commercial-launches/.

M2M services over 2G and 3G are still widely used, with a significant number of connections in the APAC region as at 2017 (Exhibit 3.7). Given that NB-IoT and LTE-M deployments commenced in 2017 in the sample markets, the majority of these connections in that year are likely to be based on 2G and 3G services.

EXHIBIT 3.7

Source: ITU

M2M CONNECTIONS IN A SAMPLE OF APAC MARKETS, 2017[14]



Some applications using low cost end devices such as wireless point-of-sale devices are straightforward to migrate to 3G/4G simply by replacing the host equipment. However, where the equipment is of high cost and long life, migration is more problematic. A prominent example is the 2G/3G based eCall service in Europe. The service uses M2M modules embedded in cars to establish automated voice and data communications with the nearest emergency centre in the event of an accident. The eCall service was made mandatory in all European Union (EU) markets as at April 2018[15]. Considering the length of vehicle lifespan, migrating such a service is quite challenging and is likely to occur over a long period of time. Another example is smart metering services used by utility companies that exist in large numbers and require considerable investment to replace.

The most widely deployed alternatives to cellular M2M and IoT are Long Range Wide Area Network (LoRaWAN) and Sigfox protocols. These non-cellular technologies are widely supported and adopted by industry, including many mobile operators.

The number of remaining M2M connections on the legacy network and type of agreements with clients is a key input in deciding the lifetime of a legacy network. Most interviewed operators, who have already retired their 2G network, had a relatively small number of M2M connections. This is the case in most emerging markets in APAC. Nevertheless, in some cases, such as in Singapore, disputes had to be resolved as to who should bear the migration cost. In New Zealand, some operators worked with clients individually to facilitate migration. Driven by an agreement to support more than a million GSM/GPRS based connections for smart metering, one operator in New Zealand still maintains a GSM network. Nevertheless, its 2G network was rationalised in capacity in view of declining 2G voice traffic.

14. M2M connections in Singapore were not recorded in the ITU database. However, interviews with IMDA in Singapore revealed that the number of M2M connections in Singapore was insignificant in 2017.
15. European Commission (2018). eCall in all new cars from April 2018, April 2015. Can be retrieved at https://ec.europa.eu/digital-single-market/en/news/ecall-all-new-cars-april-2018

Dedicated mobile broadband

Dedicated mobile broadband using dongles and small mobile modems represents a significant proportion of mobile operators' business. Markets such as Australia and South Korea reported more than six million connections each in 2017[16]. However, these connections are likely to be already based on 4G wherever 4G is deployed, particularly in high-income markets. 4G mobile data connections typically cost less than 3G/HSPA connections and provide more capacity, thus generating more value for the customer and operator[17].

Fixed wireless broadband

Fixed wireless access (FWA) broadband is used mainly in rural areas where it is uneconomical to deploy fixed wireline broadband. These systems typically involve the installation of dedicated outdoor antenna. As such, they require a substantial investment compared to a dedicated mobile broadband connection. While most of these systems are now based on 4G, 3G FWA is still in use where there is no 4G coverage. However, the number is diminishing with increased 4G penetration in rural areas across APAC.

A relatively high penetration of smartphones is a key enabler for migrating voice services from 2G to 3G. However, the main barrier for migrating 3G voice services to 4G is likely to be the low penetration of VoLTE enabled smartphones. M2M connections are likely to be the major challenge for 2G and 3G, especially where the operator has existing large-scale contracts, such as with utility companies. A summary of the main dependent services and comments on alternatives and their viability is provided in Exhibit 3.8.

EXHIBIT 3.8

Source: Network Strategies

2G/3G DEPENDENT SERVICES AND VIABILITY OF ALTERNATIVE SOLUTIONS

Service	Alternative	Coverage in case study markets	Comments
2G and 3G voice	4G/VoLTE	4G coverage exceeds 97% in case study markets. VoLTE launched in all markets by the major mobile operators.	The penetration of VoLTE enabled devices is limited and device prices are higher than 3G smartphones
2G/3G M2M	4G NB-IoT	Available in all case study markets. However, not all mobile operators have deployed this.	Good alternative for low data rate applications previously using 2G. However, current standard does not support connectivity across base stations.
	4G LTE-M	Available in all case study markets. However, not all mobile operators have deployed this.	Provides higher bandwidth than 2G and supports full mobility.
	LoRaWAN	Available in all case study markets. However, coverage is typically less than cellular IoT.	Good alternative for low data rate applications previously using 2G. Uses unlicensed frequency bands. Supports mobility.
	Sigfox	Available in all case study markets. However, coverage is typically less than cellular IoT.	Very low data rates restrict the range of applications.
Dedicated mobile broadband	4G	4G coverage exceeds 97% in case study markets.	Easily replaceable by low cost 4G mobile modems
3G fixed wireless broadband	4G	4G coverage exceeds 97% in case study markets.	Requires upgrade of modems and outdoor antennas in some cases. Number of existing connections is likely to be very small.

16. ITU (2019). ITU World Telecommunication/ICT Indicators Database. ITU, 2019.
17. Realwireless (2011). 4G Capacity Gains. Report for Ofcom, Real wireless, January 2011.

3.4 Regulatory aspects

3.4.1 Is there a distinction between 'regulator-led' and 'operator-led' switch-off efforts?

The distinction made between 'regulator-led' and 'operator-led' network rationalisation is a false one as these approaches are not mutually exclusive. Most service closures internationally are operator-led – however, this does not preclude government input in the process. As the Australian case study demonstrates, there may be overlap between the two approaches. Although MNOs in Australia are largely free to decide if and when to retire mobile technologies, the ACMA initiated a review of the 900 MHz band amidst the 2G process of the Australian MNOs.

Further, governments and regulators may also be involved in 2G/3G switch-off as a way of partnering with operators. For example, in Singapore the 2G switch-off that took place in 2017 was operator initiated with the consent of the regulator, and the IMDA helped inform the public. The regulator's role was mainly determined by its responsibilities with respect to consumer protection and service licensing. In Macao, SAR, the 2G network was retained for a considerable time period to ensure roamers from China were able to obtain service when visiting the territory.

Learning from this, successful network switch-off projects typically involve a collaboration between MNOs and regulators to achieve the optimal outcome in terms of modernising old networks and ensuring improved quality of service for consumers.

3.4.2 Spectrum management issues

Coupled with the move towards larger contiguous blocks of IMT spectrum in the 5G New Radio (5G NR) world, there are important spectrum management issues that need to be addressed with any 2G or 3G network switch-off. For example, the ACMA is currently reviewing the allocation of 900 MHz spectrum in Australia. After more than 25 years since the deployment of GSM in Australia, each of the three major mobile operators has been allocated approximately 2×8.4 MHz or 2×8.2 of 900 MHz (a total of 2×25 MHz). However, in the future the band will be refarmed in to five lots of 2×5 MHz. In Malaysia, the regulator in relation to its refarming and renewal of the 900 and 1,800 MHz bands has repacked these into 2×5 MHz blocks. Given the typical duration of licences (between 15 to 20 years), early planning by national regulators is critical for optimal usage of refarmed spectrum post any switch-off. Waiting until after any switch-off may result in those legacy IMT spectrum allocations being unduly extended into the future.

Future spectrum lots in any spectrum auction or allocation process should ideally be in 5 MHz lots for FDD or perhaps 10 MHz for TDD spectrum bands. For example, in the Philippines the 700 MHz allocations of 2×17.5 MHz to Smart and Globe Telecom mean that 2×2.5 MHz of valuable sub-1 GHz spectrum are unable to be used by the technology and ought to be returned for re-allocation by the NTC. Given the technical and commercial benefits of having 20 MHz blocks for 4G and 100 MHz (or at least 50 to 60 MHz) blocks for 5G services, larger minimum lots ought to be considered for such spectrum allocation processes.

Spectrum refarming for 3G, 4G and 5G

Depending on their traffic patterns, the devices in use by their customer base and spectrum holdings, MNOs, if they are permitted by a market's regulatory regime, refarm inter alia 900 MHz from 2G to 3G and/or 4G and 1,800 MHz from 2G to 4G. Likewise 2,100 MHz is often refarmed from 3G to 4G services. As highlighted by the APT:

> *Rather than deciding how much spectrum to leave, the question should be how efficiently used is the GSM spectrum… Spectrum re-farming can be performed in steps and will continue as traffic begins to migrate to the newer technologies. One of the first considerations for re-farming is to determine the spectral efficiency of a GSM network considering current traffic load.*

Such refarming is done on a step by step basis and may be done nationwide or regionally. For example, in Indonesia, all of the major MNOs have refarmed at least 2 × 5 MHz of 900 MHz nationally for 4G services. In Thailand, MNOs who held spectrum licences for 2 × 15 MHz in 2,100 MHz band, previously refarmed 2 × 10 MHz for 4G in Bangkok, while in other parts of Thailand only 2 × 5 MHz was refarmed for 4G, given the different customer demand and devices on their networks. While 4G is now preferred given its spectral efficiency, previously many MNOs increased their wireless broadband coverage by using 2 × 5 MHz of 900 MHz spectrum to deploy HSPA as HSPA at 900 MHz had approximately 6dB better coverage than HSPA at 2,100 MHz (eg Singtel Optus in Australia[19]).

18. APT, Report on Migration Strategy of GSM to Mobile Broadband, APT/AWG/REP-53, September 2014, page 16
19. See GSA, UMTS900 – A Case Study Optus, June 2009.

In terms of co-existence between 2G and 3G/4G in adjacent frequencies there are well-known interference and intermodulation issues which are best managed by the MNO. The preferred scenario is to use coordinated 2G and 3G/4G sites and the 3G/4G carriers sandwiched in-between GSM carriers. While a typical 3G/WCDMA carrier is 2 × 5 MHz, technical options exist to utilise as little as 2 × 3.8 MHz, while 4G can be deployed in 1.4, 3 or 5 MHz of spectrum depending on the band.[20] MNOs refarming spectrum as part of any network migration should do so in steps subject to applicable technology limitations.

Also, 2G and 4G networks can share a minimum of 2 × 6.2 MHz at 900 or 1,800 MHz. The minimum bandwidth for GSM is 2 × 2.4 MHz,[21] considering broadcast control channel (BCCH) configuration of 4x3 in a typical network. With dynamic spectrum sharing, 2G, 3G, 4G could, along with NB-IoT services, share spectrum and gradually migrate 2G traffic to 3G and 4G. Dynamic spectrum sharing (DSS) allows some of the idle 2G spectral resources to be shared with the 3G or 4G network when the service load on the network is below a specific threshold. On that note, new DSS techniques aim to allocate resources on the same band for 4G and 5G NR dynamically, without the need to refarm the band partially or entirely for 5G, so that 5G coverage can be provided in additional areas[22].

Similar sharing arrangements can also be put in place between 4G and 5G networks except that in relation to TDD networks (for example at 2.6 GHz) synchronisation arrangements may need to be put in place.[23]

3.4.3 Competition issues associated with 2G/3G switch-off

The decision to switch-off 2G or 3G networks may have significant implications for the competitive environment of a market's mobile industry. If all MNOs rationalise legacy networks at the same time then competitive issues may not arise. However there is little evidence that regulators orchestrate switch-offs for this reason. For example, in Singapore the key driver for the uniform timing of 2G switch-off was the simultaneous expiry of all MNOs' licences rather than any regulatory concern about competitive advantage.

Arguably, the strategy of large market players with respect to legacy technologies will exert considerable influence on switch-off timing. For instance, Telstra has largely driven the 2G process in Australia, putting pressure on its competitors to follow suit.

Another example is where the incumbent mobile operator with a larger share of 2G customers may argue that newer entrants/smaller mobile operators should be prohibited from switching off their legacy 2G services in advance of an industry-wide switch-off. This may be chilling to competition and innovation as there are likely to be competitive benefits from transitioning a mobile operator's customer base to IP services. In particular, where the dominant mobile operator has a materially larger allocation of IMT spectrum, there is an opportunity for the smaller mobile operator to maximise the use of its IMT spectrum and attract higher ARPU customers who may be using 3G or 4G and in the future 5G services.

There is also the possibility that:

- Mobile operators with a focus on voice-only services or small allocations of spectrum will be under pressure to merge or be acquired, particularly where their competitors have large spectrum portfolios; and
- There will be competition impacts in downstream markets for backhaul and transmission services and tower services. The switch-off of 2G and especially 3G services will result in substantially increased demand for fibre backbone services. Where mini-links and other microwave services were previously sufficient for voice-only services this is unlikely to be the case in the future.

20. This is for 850 MHz (Band 5), 900 MHz (3GPP Band 8), and 1800 MHz (Band 3). While the minimum supported bandwidth for 700 MHz (Band 28) is 3 MHz, and for 2100 MHz (Band 1), 2300 MHz (Band 40), and 2600 MHz (Band 7 and 41) it is 5 MHz. See http://niviuk.free.fr/lte_bandwidth.php
21. It is understood that at least one equipment vendor will support GSM with as little as 2 x 1.2 MHz of FDD spectrum.
22. Ericsson ESS Solution https://www.ericsson.com/en/portfolio/networks/ericsson-radio-system/radio-system-software/ericsson-spectrum-sharing
Huawei CloudAIR Solution https://www.huawei.com/en/about-huawei/publications/communicate/85/huawei-cloud-air-2-unleashes-all-spectrum
ZTE Magic Radio solution https://www.zte.com.cn/global/about/magazine/zte-technologies/2016/2/en_721/449147.html
23. See GSMA, Roadmap for C-Band spectrum in ASEAN, August 2019, Appendix D, page 73

3.5 Costs versus benefits

Both consumers and producers / suppliers may benefit from the rationalisation of legacy technologies. Potential benefits for society include:

- Access to a wider range of innovative services and applications, particularly if consumers purchase smart devices;
- Potentially faster broadband speeds over refarmed legacy spectrum;
- Potential improvements in 4G and 5G coverage as well as quality of service if refarming results in the availability of more sub-1 GHz spectrum; and
- Society in general achieving more value from limited spectrum resources.

For operators, opportunities include:

- Refarming legacy spectrum and deploy more cost efficient / spectrally efficient network technology
- Achieve operational cost savings
- To position or rebrand as an innovative MNO offering the latest technology
- Competitive advantages, particularly when operators do not migrate their networks at the same pace, with one or more MNOs undertaking early switch-off, leading to churn of lower ARPU/non-profitable customers to another MNO
- Ability to meet increased demand for wireless broadband through carrier aggregation of refarmed spectrum
- Ability to offer greater coverage if the switch-off process releases sub-1 GHz spectrum which may be used to deploy newer technology services
- Utilise less power, deploy solar and other substitutes and reduce the carbon footprint of the network.

However, there can be a number of challenges. A regulatory mandate or intervention can either enhance or mitigate these, depending on market context and how the switch-off is managed. For the operator potential risks include:

- Customer churn, particularly when operators do not switch-off their networks at the same pace;
- The cost of migrating a large number of M2M connections depending on the market;
- Possible reduced coverage, particularly if the new technology operates in a frequency band that does not provide adequate indoor coverage;
- Potential brand damage if the operator leaves particular segments of society without coverage, increases costs to consumers or disconnects large numbers of M2M connections for business customers; and
- An unfavourable regulatory intervention forcing the operator to maintain a legacy network longer to meet a very low demand.

Most of these challenges can be avoided by careful planning. This may require involving the regulator as early as possible and allowing for a reasonably long transition period to communicate with the customers and coordinate with business partners. A good example here is the case of Singapore where regulatory involvement and coordination with the operators allowed a reasonably long transition period to bring demand levels down to acceptable levels and educate the customers. The regulator in Singapore also set conditions for coverage and service offerings that met the needs of all segments of the customer base. We note also that increasing prices are unlikely in a competitive market, where the deployment of newer and more efficient technologies has historically led to more affordable services over time.

4. Key lessons

4.1 Different drivers for different markets

Case study markets discussed in this report differ in terms of the mobile market characteristics, extent of regulator involvement and spectrum management. As such, the impact of each of the key drivers on the decision to switch-off 2G varied from market to market, with spectrum related issues being the most prominent drivers (Exhibit 4.1), as well as declining 2G demand as the penetration of smart devices increases.

EXHIBIT 4.1

Source: Network Strategies

KEY SWITCH-OFF DRIVERS IN CASE STUDY MARKETS

Market	Spectrum reuse for 3G/4G	Spectrum harmonisation	Spectrum license expiry	Cost optimisation	Declining 2G demand
Australia	■			■	■
Japan		■		■	
Macao, SAR	■				■
New Zealand	■			■	■
Singapore	■		■		■
South Korea	■			■	■

The switch-offs of 2G services proceeded largely without any conflicts, either with the regulator or the customer base. Regardless of market specifics and regulator involvement, the processes share common characteristics.

4.2 Characteristics of a successful switch-off

The legacy network rationalisation processes were largely initiated by the operators, with varying degrees of regulator involvement. Despite the differences in switch-off timing and market, the key to successful 2G switch-off processes lies in careful planning and transitional processes, seeking regulatory approval where necessary, and above all ensuring effective customer engagement.

Regulatory involvement in switch-off process ranges from zero to highly prescriptive

- Operators typically initiate legacy shutdown plans;
  - usually operators switch off at different times (Australia, Japan, New Zealand, South Korea) rather than all at the same time (Singapore)
- Consumer protection is key regulatory consideration;
  - possible requirements for size of user base at switch-off
  - agreements on transition timetable
  - potential matching coverage obligations
  - affordability issues – cost of devices and plans
- Some regulatory regimes require approvals for changes in use of spectrum / service availability, particularly if spectrum allocations are not technology neutral; and
- Some regulators oversee / engage directly in the transitional process (e.g. Singapore).

The transitional period is typically around three years

- Operators commence preparations for network rationalisation long before making any public announcements. On average, the process takes three years from initial decision-making to switch-off. However, the process can be shorter if adoption rates of new generation mobile technologies are relatively high (e.g. in New Zealand a longer transitional period was required for the Spark switch-off in 2012 compared to the 2degrees switch-off in 2018);
  - early switch-offs required relatively long transition periods for this reason (e.g. an early switch-off in South Korea with a proposed short transition period precipitated regulatory intervention and legal challenges);
- Contractual and regulatory obligations, particularly with vendors and business customers, may have an impact on timing, as might the age of the deployed mobile networks;
- Emerging alternatives to 2G, such as NB-IoT can facilitate legacy service migration (e.g. M2M); and
- The transitional period is essential to facilitate customer migration to new technologies.

Reasonable formal notice periods are essential

- Public announcement of switch-off varies according to specific market circumstances such as level of demand and adoption rate of newer technology;
- The expiry of spectrum licences may be a catalyst for transition (e.g. Thailand);
- A very short notice period may lead to customer dissatisfaction (e.g. KT experience in South Korea following an announcement giving three months' notice) or network issues as to how to handle the additional traffic (e.g. Macao, SAR); and
- Fair trading rules and / or other legal obligations towards customers need to be considered.

A smooth switch-off requires a carefully planned communications / marketing campaign

- Use of different media to communicate timing of switch-off;
- Intensive marketing campaigns for alternative 3G/4G services and smartphones, including using TV commercials;
- Direct engagement with certain demographics, such as older consumers, may be necessary, including educational programmes (South Korea);
- Contractual arrangements with business customers (e.g. M2M, IoT contracts) may need individual attention and communications (Australia); and
- Government / regulatory involvement may emphasise that the switch-off is officially endorsed rather than a marketing ploy.

Incentives for subscribers also play an important role

- Discontinue sale of 2G handsets, potentially prior to public announcement, to facilitate migration to smartphones (e.g. Singapore);
- Offer free or discounted devices and waive related administrative fees (e.g. Australia and Japan);
- Offer 2G subscribers continuation of existing mobile plans at no additional cost – retain numbers and subscription plans on the 3G/4G networks at no additional cost and with no re-contract (e.g. Singapore);
- Ensure that a range of handsets is available to meet various customer needs, from basic models to feature-rich smartphones, and make handsets with features similar to 2G phones available (e.g. Singapore);
- Support for senior users – partnerships with community groups to reach out to seniors for providing support for the upcoming switch-off (e.g. Singapore);
- Introduce attractive switching plans (possibly including offering affordable smartphones and / or handset subsidies); and
- Offer assistance with recycling handsets to remove from ecosystem.

Deciding whether to switch-off 2G or 3G first is a matter of economics

- Long-term agreements to support M2M connections on 2G is a key factor in maintaining 2G longer than 3G services;
- Size and type of subscriber base by technology may lead to divergent approaches by MNOs in the same market;
- Current and forecast revenues by technology, including roaming revenues; and
- Availability of substitutes for existing services using 2G / 3G technologies.

The demand threshold for switch-off varies considerably

- Some regulators request less than 1% demand for switch-off approval (e.g. South Korea);
- Anecdotal evidence that some operators may consider 10% a suitable threshold as the trigger to initiate legacy network switch-off (e.g. Australia, Singapore); and
- ARPU may be a key driver rather than number of subscribers (e.g. Spark New Zealand).

Little support for maintaining a single network with roaming obligations

- While some markets briefly considered this approach, many practical difficulties were identified, including:
  - cost implications for the operator maintaining legacy technology
  - potential competitive issues in the market
  - interoperability issues as operators' networks may be based on differing vendor equipment.
- One alternative may be to maintain a 2G network utilising only a small slice of spectrum (e.g. for roamers as in Macao, SAR).

Matching 3G coverage is a pre-requisite

- Operators have achieved a level of 3G coverage matching 2G coverage before switching off 2G to allow for the newer technology to diffuse in the customer base. The same process is being followed in relation to 3G switch-off with MNOs ensuring that 4G VoLTE coverage matches today's 3G coverage (e.g. Telstra in Australia).

Maintaining Quality of Service during and after the transition is vital

- Transition periods need to be long enough to allow optimisation of the successor mobile technology; and
- The availability of sub-1 GHz spectrum for the successor technology is essential to provide adequate indoor coverage. For example, 4G coverage with 700 MHz is likely to help the transition in Australia.

As noted above, the process lasts typically three to four years, from the time the operator makes the decision until the switch-off takes place, including phases of preparation, facilitation and public engagement.

The conflicting issues and facilitators of the switch-off are summarised in Exhibit 4.2. It is important to note that in a competitive market the conditions for a successful switch-off are usually fulfilled by market drivers without regulatory intervention, as in the case of New Zealand. A key facilitator in that market is the availability of technology neutral spectrum rights that allow the operator to rationalise 2G spectrum and reuse it to meet increasing demand for 4G. However, for mandated and simultaneous switch-offs, regulatory supervision may be necessary to facilitate the switch-off and safeguard consumer rights.

EXHIBIT 4.2

Source: Network Strategies

PROCESS FLOW OF SWITCHING OFF A 2G NETWORK

4.3 The future of 3G

3G networks are likely to be operational for at least five more years in most of the case study markets. Based on discussions with MNOs, equipment vendors and regulators, many MNOs in APAC which are yet to switch-off any legacy network are actively considering whether it is possible to concurrently profitably deploy, operate and maintain 2G, 3G, and 4G networks in addition to 5G networks which are being planned and/or deployed.

Decisions for each operator will depend crucially on demand evolution in the particular market. The likely key drivers for 3G switch-off are the same as for 2G – in particular, cost reduction and frequency reuse. Key factors that will determine the switch-off date include:

- The adoption rate of VoLTE enabled devices by customers
- Ensuring high-quality marketwide 4G coverage capable of supporting VoLTE services after 3G switch-off
- The level of demand on the 3G network including:
  - M2M connections and the speed at which legacy services are replaced with IoT services using IP connectivity
  - roaming revenues
- The move to reduce power usage and hence the carbon footprint of cellular networks
- Market and MNO 5G deployment plans.

As such, markets with early 4G VoLTE deployments and high penetration rates of VoLTE handsets are likely to switch off 3G completely. The release of more sub-1 GHz bands (such as the 700 GHz band) will also be vital for 5G deployment. This spectrum, aggregated with the mid-band spectrum (particularly 3.5 GHz) and millimeter wave (mmWave) spectrum, is necessary to provide the optimal combination of coverage and capacity for 5G.

Annex A: Australia: 2G and 3G switch-off

In Australia, all three MNOs have switched off their 2G services. Telstra switched off in December 2016, with Singtel Optus following by August 2017 and Vodafone Australia in June 2018[24]. In relation to 3G services, Telstra switched off 3G connectivity on its 2,100 MHz spectrum on 25 March 2019. The operator has also announced the eventual switch-off of 3G technology in June 2024[25]. Vodafone switched off 3G services at 2,100 MHz in 2019 but will continue to operate 3G services on 900 MHz spectrum. Singtel Optus has yet to announce 3G service shutdown plans.

A.1 Mobile market

Market players

There were approximately 28 million mobile phone services in Australia as of 30 June 2019, up from 27 million as at 30 June 2018[26]. Venture Insights forecasts the mobile market will remain the largest segment in the overall Australian telco market with AUD22.3 billion in revenue by 2022[27].

The Australian mobile market is dominated by the three major MNOs – Telstra, Singtel Optus, and Vodafone, each of which owns and operates its own network. At the time of its 2G switch-off in 2016, Telstra was already the largest player in the mobile market.

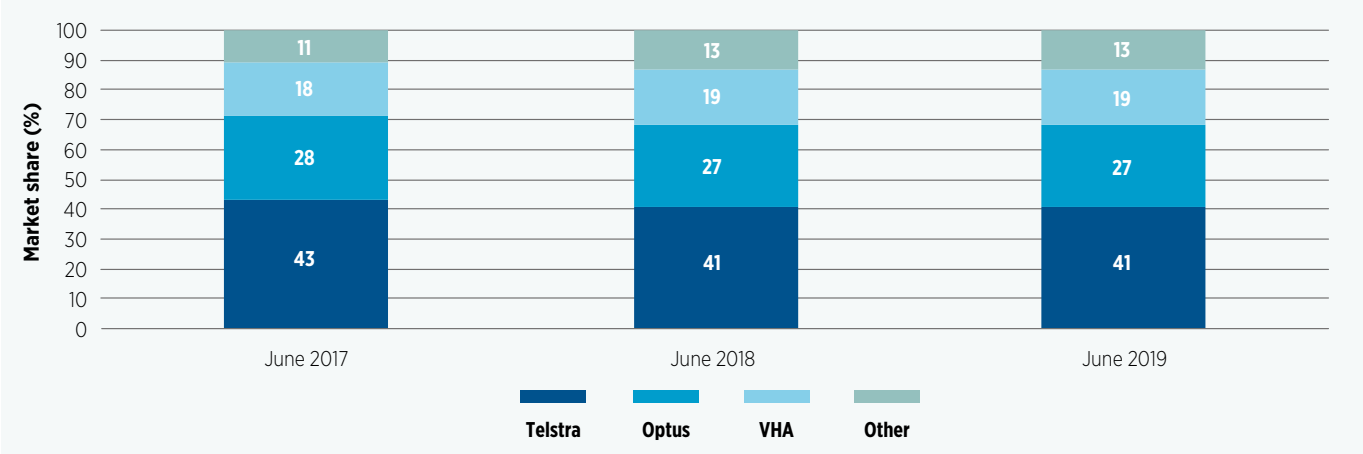
Retail market share for mobile handset services has remained stable since 2014, with Telstra maintaining a 41% share, followed by Singtel Optus at 27%, Vodafone at 19% and mobile virtual network operators (MVNOs) at 13%

As Exhibit A.1 below shows, the market shares of these operators have remained largely unchanged in recent years as Singtel Optus and Vodafone followed Telstra in switching off 2G. While MVNOs have grown market share in recent years, their market share appears to have stabilised in the past two years, accounting for around 13% of services in both 2017–18 and 2018–19[28].

EXHIBIT A.1

Source: ACCC 2018-19

RETAIL MARKET SHARE FOR MOBILE PHONE SERVICES FROM 2016-17 TO 2018-19[29]



24. "The Potential Impact of Switching Off 2G in the UK: A Report for the UK Spectrum Policy Forum by Real Wireless", October 2019.
25. https://exchange.telstra.com.au/1-2-3-4-and-5-the-continuing-evolution-of-our-mobile-network/
26. https://www.accc.gov.au/system/files/Communications%20Market%20Report%202018-19%20-%20December%202019_D07.pdf
27. https://www.ventureinsights.com.au/product/australian-mobile-telco-market-outlook/
28. https://www.accc.gov.au/system/files/Communications%20Market%20Report%202018-19%20-%20December%202019_D07.pdf.
29. ACCC Communications Market Report 2018-19, December 2019.

There is also a significant number of MVNOs in Australia: These companies purchase wholesale mobile services from the MNOs, provide services under their own brand and typically provide their own billing and customer care. Key MVNOs in Australia include Amaysim, Kogan Mobile, Aldi Mobile, Ovo Mobile, Boost Mobile, Lebara Mobile and Virgin Mobile as well as new entrant circles.life.

Allocation of network frequencies

The allocation of network frequencies in Australia to the three operators is shown below in Exhibit A.2. As all MNOs have switched off their 2G networks, there are no longer any allocated 2G frequencies. It should be noted that Australian IMT frequency allocations are complex as all IMT spectrum over 1 GHz is allocated on a regional basis.

EXHIBIT A.2

Source: ACCC, Allocation limits advice for the 26 GHz spectrum allocation: Consultation Paper, February 2020 as updated

AUSTRALIAN NETWORK FREQUENCIES

MNO	Major Cities[30]	Regional areas[31]	3G	4G	5G
Telstra	Minimum 264.8 MHz Maximum 329.3 MHz	Minimum 374.3 MHz Maximum 517.3 MHz	850 MHz	700 MHz 900 MHz 1800 MHz 2100 MHz 2600 MHz	850 MHz (soon to be repurposed) 3.4/3.6 GHz
Singtel Optus	Minimum 309.8 MHz Maximum 354.8 MHz	Minimum 291.8 MHz Maximum 367.3 MHz	900 MHz	700 MHz 1800 MHz 2100 MHz 2300 MHz 2600 MHz	2300 MHz 3.4/3.6 GHz
Vodafone/TPG	Minimum 236.4 MHz Maximum 256.4 MHz	Minimum 126.4 MHz Maximum 231.4 MHz	900 MHz	700 MHz 850 MHz 1800 MHz 2100 MHz 2600 MHz	700 MHz 3.6 GHz

Mobile experience

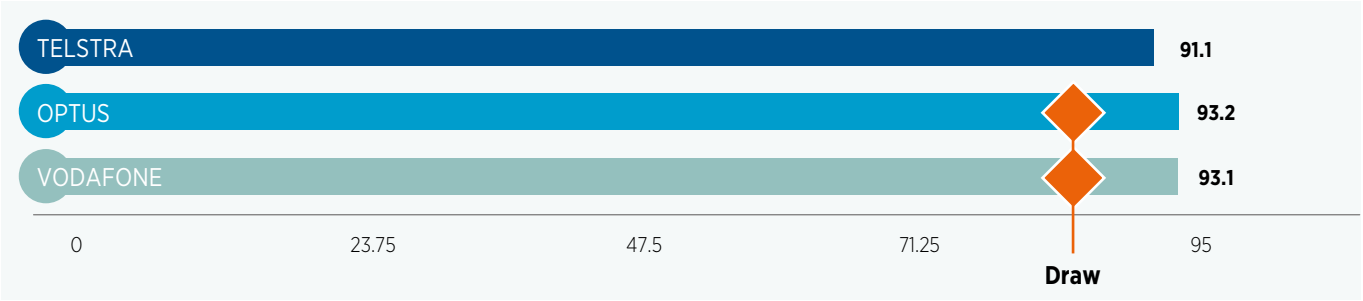
In terms of coverage, there has been significant improvements in 4G availability[32] since the commencement of 2G switch-off in Australia in 2016. According to an Opensignal study, 4G customers on the three networks were then able to obtain an LTE signal more than 70% of the time. Vodafone 4G customers were able to connect to its LTE network 77.6% of the time, while it was 76.27% for Telstra users. Singtel Optus was slightly behind both with an availability rating of 73.4%. As at October 2019, all three of Australia's mobile operators were able to offer a 4G signal to users more than 90% of the time (Exhibit A.3). As assessed by Opensignal, Telstra's 4G availability may increase as the operator will be closing its 3G network by 2024 to clear spectrum for 5G and also plans to boost its 4G coverage to match its 3G network[33].

30. Including Sydney, Melbourne, Adelaide, Perth and Brisbane
31. Including Canberra, Darwin and Hobart
32. Note that availability does not measure geographic or population coverage. Open Signal's availability tests represent the typical experience customers are seeing on their operators' networks wherever they happen to be: https://www.opensignal.com/reports/2016/06/australia/state-of-the-mobile-network
33. https://www.zdnet.com/article/telstra-optus-tpg-vodafone-win-5g-spectrum/

EXHIBIT A.3

Source: Opensignal, 2019

4G AVAILABILITY AS OF OCTOBER 2019 (% OF THE TIME)[34]



The effect of 5G on the mobile market

All MNOs are continuing to invest and expand their networks in preparation for wider 5G deployment. This includes investing in spectrum suitable for 5G, which was first auctioned in December 2018, and continuing to expand network coverage, including co-investing with government in regional mobile blackspot areas.

Indeed, Telstra and Singtel Optus have commenced deploying 5G mobile network infrastructure in select areas of Australia. While this coverage is currently limited, it represents the likely next significant point of differentiation between the MNOs. Initially, 5G networks will leverage existing 4G networks before becoming standalone. There is also the potential for mobile services to provide a competitive constraint against national broadband network (NBN) services depending on how these services are offered and priced[35].

TPG – Vodafone merger

A recent mobile market development is the merger between Vodafone and TPG Telecom Limited (TPG). The deal was orginally announced in August 2018, following TPG Group's decision in 2017 to launch its own mobile network.

Following an informal merger review, the Australian Competition and Consumer Commission (ACCC) announced in May 2019 that it would oppose the merger due to concerns about a substantial lessening of competition in the retail mobiles market.

However, that decision was appealed and in February 2020 the Australian Federal Court approved the merger. Contrary to the ACCC's initial ruling, the court held that the merger would not substantially lessen competition in the Australian mobile market. It accepted that while TPG may have had thoughts of resurrecting the mobile network plan, this would have been unlikely for at least five years. Vodafone and TPG expect to complete the merger in mid-2020, provided the ACCC does not lodge an appeal.

A.2 Key drivers

The decisions by Australian MNOs to close legacy networks are driven by a number of considerations.

First, switching off networks allows the deployment of networks utilising the higher spectral efficiency of 4G and 5G, and freed-up frequencies can be used to increase wireless broadband coverage and bandwidth speeds through carrier aggregation. According to Telstra, it switched off its 2G network to provide more spectrum for 4G technology and is planning to do the same in relation to 3G technology[36]. The operator highlighted that an important driver in its decision to switch off both 2G and 3G technologies is ensuring that it is utilising spectrum in the most efficient way to maximise commercial returns on what Telstra considers to be a very expensive asset. As spectrum remains one of the largest single cost factors for owning and operating mobile networks, it does not make commercial sense for Telstra to restrict spectrum to older technologies once the user base of these technologies substantially declines.

Similarly, Singtel Optus stated it was switching off 2G to focus and invest in technology that offers better services such as its 4G network[37]. Vodafone Australia also stated that switching off legacy 2G networks allows greater broadband speeds, less latency, and improved call quality offered by 3G and 4G services[38].

34. Open Signal, "Australia Mobile Network Experience Report", October 2019.
35. https://www.accc.gov.au/system/files/Communications%20Market%20Report%202018-19%20-%20December%202019_D07.pdf
36. https://exchange.telstra.com.au/1-2-3-4-and-5-the-continuing-evolution-of-our-mobile-network/
37. https://yescrowd.optus.com.au/t5/Blog/2G-Network-Closure-Update/ba-p/178495
38. https://www.vodafone.com.au/red-wire/goodbye-to-2g

Second, 4G and 5G networks also offer significantly higher network efficiency/lower network capex and opex costs compared with either 2G or 3G networks. It is uneconomic for MNOs to own and operate (including provide spares, staffing etc) for 2G, 3G, 4G and 5G networks concurrently. As such, some rationalisation is needed to lower the operating complexity of running three or four different networks.

As 2G usage declined and the infrastructure became increasingly costly to maintain and support, all three Australian MNOs ultimately chose to fully switch off their 2G services[39]. The operators have opted to invest in modern technologies such as 4G and 5G services. As Telstra noted, there is nothing that 2G and 3G offer that later technologies cannot do as well or better. It would be an inefficient use of resources such as spectrum to continue their operation.

Telstra has however indicated that future 3G network closure will be more complex because it involves a larger M2M migration, will remove voice services for those who do not have 4G VoLTE compatible devices, and requires 4G coverage to be expanded to match the 3G coverage. To manage these issues Telstra has allowed significantly more time leading up to closure in June 2024. Like the 2G switch-off, Telstra expects the ongoing natural migration of handheld 3G devices to later technologies will assist with minimising residual issues at the time of closure.

Third, the fact that certain telecommunications providers begin to shut down their traditional networks to accommodate new technologies, and therefore new services, may also indirectly force other telecommunications providers to take similar action[40]. When Telstra shut down 2G services in 2016, its competitors followed a similar path. As such, it is possible that a similar pattern will occur in Australia in relation to 3G, and both Optus and Vodafone will announce 3G networks switch-off at some future time.

Switching off 2G or 3G first?

The decision as to which network should be turned off first (2G or 3G), and how to do so, depends on various factors that may vary according to the interests of individual telecommunications providers and geographic regions.

For instance, one important factor to consider is how significant the 2G footprint remains in the market. MNOs should ensure that those consumers affected by the switch-off are a low percentage of the total base. According to the Ericsson Mobility Report published in June 2019, the number of 2G/3G subscribers is expected to decline by around 900 million throughout the world by 2024, a reduction of approximately 120% compared with 2018.

Indeed, Australian MNOs have opted to prioritise the cessation of 2G technology over 3G, in part due to the declined usage of 2G services by consumers. According to Telstra, at the time of switching off 2G services, 2G mobile traffic accounted for less than 1% of its total mobile network traffic[41]. Singtel Optus also stated that it was "the right time for us to close the 2G network" due to the decreasing customer levels using the 2G mobile network as greater smartphone usage and advances in 4G technologies drive customer preferences for mobile data and faster speeds[42].

Ultimately, the contrasting Australian and European experience demonstrates that deciding whether to turn of 2G or 3G services first is highly dictated by what makes most business and strategic sense for mobile operators given their unique situations.

A.3 Challenges

Voice service

Telecommunications providers often need to maintain traditional 2G/3G networks in order to support voice services because, in theory, 4G technology does not support this service in circuit-switched mode. To solve this, VoLTE technology provides a more efficient solution for voice services than 2G/3G technology[43].

VoLTE is a feature that allows voice calling over 4G networks. It allows consumers to remain connected to the 4G network during calls, which means they can continue using 4G mobile data while making and receiving calls[44]. MNOs need low sub-1 GHz spectrum such as APT700 in order to optimally deploy robust VoLTE services especially in relation to in-building coverage. In the interim, voice calls will use circuit switch fall back (CSFB) to the 2G/3G networks where necessary (ie where there is no LTE coverage or VoLTE has not been deployed).

40. https://nae.global/en/the-status-of-the-2g-3g-network-sunset/
41. https://exchange.telstra.com.au/make-switch-2g-network/
42. www.optus.com.au/about/media-centre/media-releases/2017/07/optus-to-complete-2g-network-turn-off
43. https://nae.global/en/the-status-of-the-2g-3g-network-sunset/
44. www.vodafone.com.au/support/network/volte

Importantly all thee operators in Australia offer VoLTE. Vodafone who uses its 850 MHz for such services, has said that, "VoLTE fully integrates voice and data for a better customer experience. It allows mobile phone users to talk on their device and access 4G data at the same time, instead of the current technology which sees smartphone users drop back to 3G when making or receiving calls."[45]

M2M devices

A main challenge to switching off is the need to migrate services with a long life-cycle such as some M2M services. Key M2M use cases in Australia are vehicle telematics, asset tracking and point of sale payment terminals[46].

As part of Telstra's approach to addressing this problem, it indicated that launched the "M2M Device Purchase Plan" in partnership with Netcomm Wireless and Sierra Wireless, which allows its clients to spread the cost of purchasing the hardware over a 24-month period. Telstra also stated that "having certified M2M devices was really important to move GSMA Intelligence Cellular M2M forecasts and assumptions: 2010-2020 14 from 2G to 3G, to offset the replacement cost."[47] According to Telstra, after allowing 2.5 years to effect migration and engaging M2M customers early to help them plan their migrations., it successfully shut down its 2G service with negligible customer experience issues.

Singtel Optus also added that "customers are shifting to 3G because of 3G modules becoming cheaper, but they also understand that 2G networks will not be around forever and operators cannot ensure that the network will be in place in five to seven years."[48]

However, the challenge that M2M migration poses is greater in relation to the future 3G closure. This is because it involves a larger M2M migration; will remove voice services for those who do not have 4G VoLTE compatible phones; and requires 4G coverage to be expanded to match the 3G coverage. In order to manage these issues, Telstra has allowed significantly more time leading up to closure – nearly five years with final closure in June 2024. It is expected that the ongoing natural migration of handheld 3G services to later technologies will assist in minimising residual issues at the time of legacy network closure.

A.4 Optimal conditions

Operator-led switch off

In discussions with ACMA they emphasise that regulatory frameworks are not prescriptive as to the type of technology that can or should be used to provide mobile services. Consistent with having technology neutral IMT spectrum allocations, the decision to switch off 2G and 3G services is a commercial one left to the MNOs given the opex and opportunity costs involved. As such moving from one technology to another is a commercial decision for operators. While ACMA can and does get enquiries from consumers when a switch off is announced, it is understood that simply indicate that the consumer should talk to their service provider to determine the best course of action.

Having said that ACMA does monitor developments and respond as necessary to ensure technical and regulatory frameworks are fit for purpose. However, this is not required to be done very often as, Australian technical frameworks are designed to quite flexible so usually operators can work within the established framework when changing/upgrading technology. Any major amendments are typically done at the time when a spectrum licence is renewed to ensure the technical arrangements are optimised for the expected use while ensuring the interference envelope is maintained with other services.

However, note that there may still be some government involvement even in an operator-led approach.[49] Recently, in Australia, the decision by the three MNOs to switch off 2G services was used by the ACMA as an opportunity to conduct a comprehensive review of the 900 MHz band, including a reorganisation of the band plan[50].

45. www.vodafone.com.au/media/4g-start-volte-trails
46. "The Potential Impact of Switching Off 2G in the UK: A Report for the UK Spectrum Policy Forum by Real Wireless", October 2019.
47. www.gsma.com/iot/wp-content/uploads/2016/09/GSMA-Intelligence-Cellular-M2M-forecasts-2010-2020.pdf.
48. Ibid.
49. There was only one instance where the ACMA was involved in a switch off process. This occurred when the Australian government asked Telstra to delay the switch off of the CDMA network in 2007/08. ACMA was asked to undertake some trials to determine if coverage equivalency had been achieved between the 2G CDMA network and the then new 3G NextG network. The Australian Government then took this information into account when discussing the switch off process with Telstra.
50. www.acma.gov.au/consultations/2019-08/reconfiguring-900-mhz-band-consultation-112019

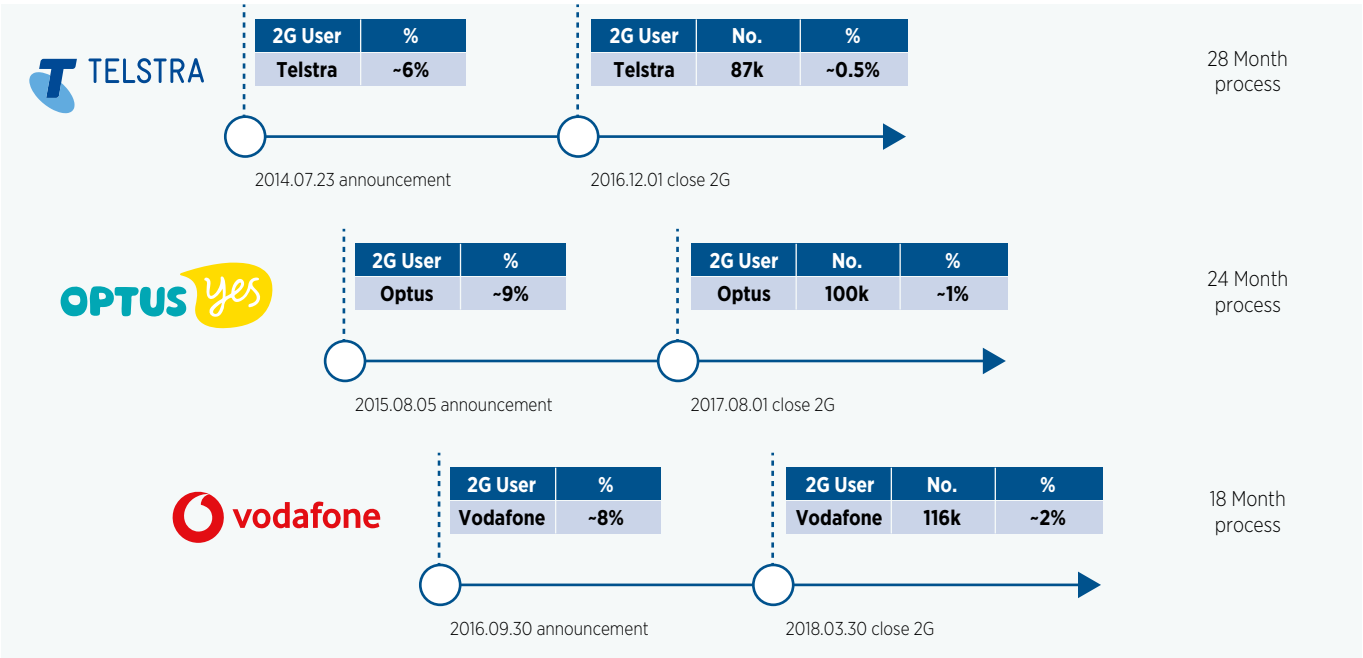
Small 2G user base

Mobile operators typically wish to start the process of switching off legacy 2G services when they fall below 10% of their user base. For example, in Australia, the customer base differed between the three operators. As such, each mobile operators was driven to have a different timeline for its switch off of its 2G network as shown in Exhibit A.4 below.

EXHIBIT A.4

Source: media and industry sources

ALL OPERATORS ANNOUNCE 2G CLOSURE WHEN 2G USERS <10%



Transition periods and information campaigns

An important issue for MNOs considering 2G or 3G switch-off is how far in advance to warn and prepare customers. Switch-off and the transition to new technologies should be supported by clear communication, careful planning and the appropriate information and marketing campaigns. Operators must also ensure that sufficient time is allowed for the majority of customers to naturally migrate, and that new technology offerings are attractive enough to facilitate this.

As shown above, Australian MNOs took between 18 to 28 months from announcement to switching off 2G. In Telstra's case, 2.5 years was the minimum period required to effect a successful 2G closure wherein there were negligible customer issues and later technology provided equivalent coverage to legacy networks. To address the challenges of consumer engagement, Telstra conducted an extensive communications campaign for consumers. First, it provided in-store lessons on using smartphones, followed by a free handheld device campaign, where over 80,000 devices were provided to customers. Telstra's device procurement reduce the number of 2G-only device it sold in its retail stroes and online and later procured lower cost smart devices with 3G and 4G or 4G only capability with VoLTE support.[51]

However, Telstra planned for a significantly longer transition period in relation to its 3G switch-off, announcing it over four years in advance. As detailed in Section A.2, this is due to the additional complications involved in M2M migration following 3G closure. This demonstrates how the length of time, and the resources invested in this process are likely to vary between human subscribers and business/M2M users, and according to the value of the 2G/3G base to the operator's particular Key Performance Indicators (KPIs).

51. GSMA, "Network Economics: Improving capacity, coverage and capability", February 2018.

A.5 Risks

From a policy perspective, it is critical that network coverage does not fall as a result of the switch-off of legacy technology and a section(s) of society (e.g. due to device costs or similar) or specific areas of the market are disenfranchised. This has adverse political as well as economic implications.

This is an issue which the ACMA in Australia has faced. To mitigate the potential impact on regional services in particular, ACMA delayed refarming the 900 MHz band in order for 4G coverage to be deployed so as to be equivalent to Australia's then 3G coverage. This also permitted the coverage of VoLTE-enabled 4G services to also greatly expand.

The ACMA considered it essential that "... VoLTE-enabled device penetration in the affected areas to reach an acceptable level before legacy apparatus-licensed 3G services potentially lose access to their current entitlements. The ACMA has decided to take the discontinuity risk into account when determining allocation timeframes ... such that the reconfiguration under the proposed way forward ... is delayed for a reasonable period while MNOs' 4G coverage improves and legitimate consumer issues are able to be addressed."[52]

A.6 Key takeaways

The key takeaways from the Australian case study are that the timing of the 2G switchoff is critical and depends on the 2G penetration of your customer base. Even then it may be necessary to fund a small percentage of 2G customer hold-outs. Going forward into the future planned switch of 3G, 4G coverage with 700 MHz and VoLTE device penetration are likely to be the key drivers of a successful transition.

52. ACMA, Reconfiguring the 890-915/935-960 MHz band: Way Forward, October 2017, page 30.

Annex B: New Zealand 2G switch-off

New Zealand has three mobile operators:

- Vodafone New Zealand;
- Spark New Zealand; and
- 2degrees.

In addition, the market includes a small number of MVNOs. Spark and 2degrees switched off their 2G networks in 2012 and 2018, respectively. The two operators have not announced plans to switch off 3G. Vodafone continues to operate 2G and 3G networks, with plans to switch off 2G in 2025. The 2G switch-offs, which were initiated by the operators, occurred with no regulatory intervention or participation.

B.1 Mobile market

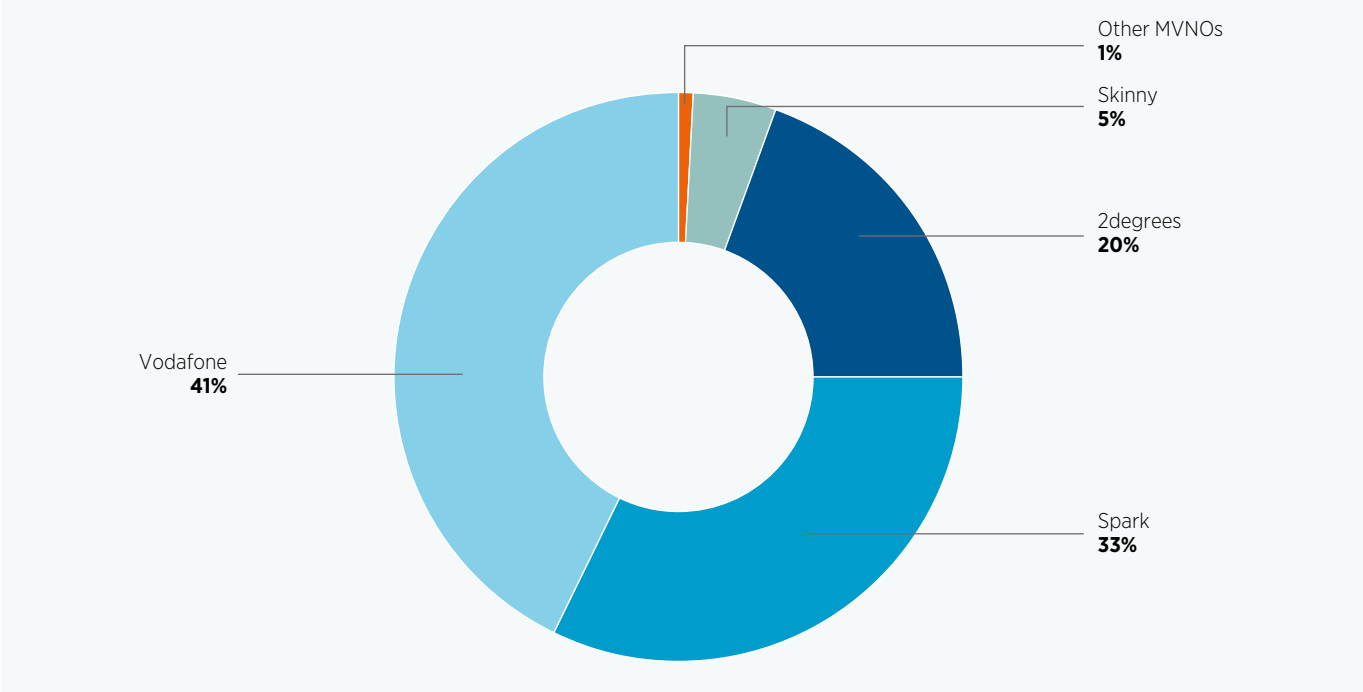
Market share

The New Zealand mobile market is dominated by three vertically integrated MNOs: 2degrees, Vodafone New Zealand (Vodafone) and Spark New Zealand. These operators control about 94% of the retail market, with mobile virtual network operators sharing the remaining 6% (Exhibit B.1) . The largest MVNO is Skinny, a sub-brand of Spark.

EXHIBIT B.1

Source: Commerce Commission

MARKET SHARE OF NEW ZEALAND MOBILE NETWORK OPERATORS IN 2019



53. Commerce Commission (2019). Mobile Market Study – Findings, Commerce Commission, September 2019.

Spark, formerly known as Telecom New Zealand, was the incumbent telecommunications operator in New Zealand until Telecom's fixed line wholesale business, Chorus, became a separate company in 2011. Vodafone has been operating in New Zealand since 1998, while 2degrees entered the market in 2009. MVNO wholesale access arrangements are not regulated. However, there are signs of increased competition to host MVNOs. Two new MVNOs have been reported as signing agreements with Vodafone and Spark in 2019, increasing the number of MVNOs and sub-brands to seven[54].

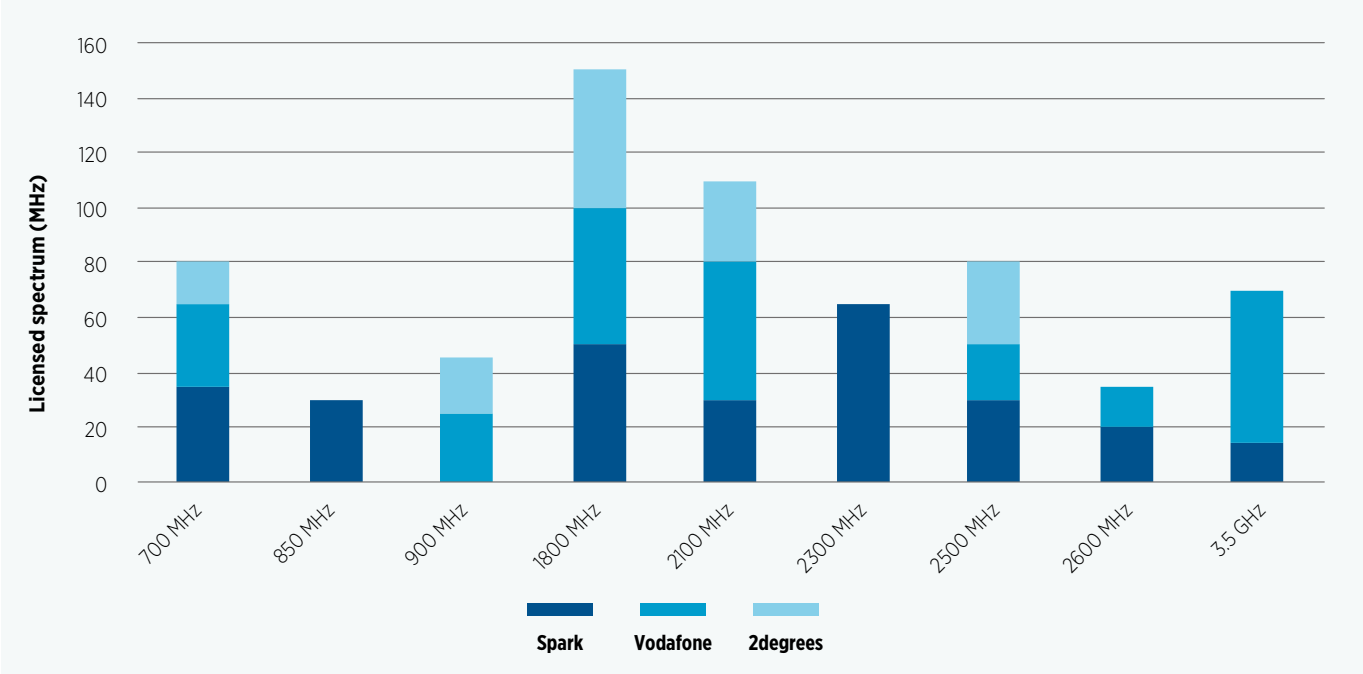
Spectrum holdings

The market share and financial capability of MNOs in New Zealand is also reflected in spectrum holdings of the MNOs. Significant asymmetries can be noted in spectrum holdings, particularly in the sub-1 GHz bands and the 3.5 GHz band (Exhibit B.2). This asymmetry has raised concerns, especially by 2degrees, that it may distort competition on both the wholesale and retail level. This stance is also shared by many MVNOs who think that the limited 2degrees spectrum (18% of total) will restrict its ability to compete with Spark and Vodafone in providing wholesale access[55]. Currently only Spark and Vodafone have management rights in the 3.5 GHz band, which will be critical for 5G early deployment. An auction to allocate 160 MHz of unused frequencies in the 3.5 GHz band is due in 2020. The spectrum will be awarded on a short-term basis (two years) and is intended to facilitate 5G deployment[56]. Mobile spectrum auctions in New Zealand are largely awarded on a technology neutral basis.

EXHIBIT B.2

Source: Radio Spectrum Management

KEY SPECTRUM HOLDINGS FOR NEW ZEALAND MNOS, AS AT JANUARY 2020



54. Commerce Commission (2019). Mobile Market Study – Findings, Commerce Commission, September 2019.
55. 2degrees (2019). Submission in response to Commerce Commission's mobile market study – preliminary findings. 2degrees, June 2019.
56. TeleGeography (2019). New Zealand to auction short-term access to unused 3.5 GHz spectrum in 2020. News release, TeleGeography, December 2019.

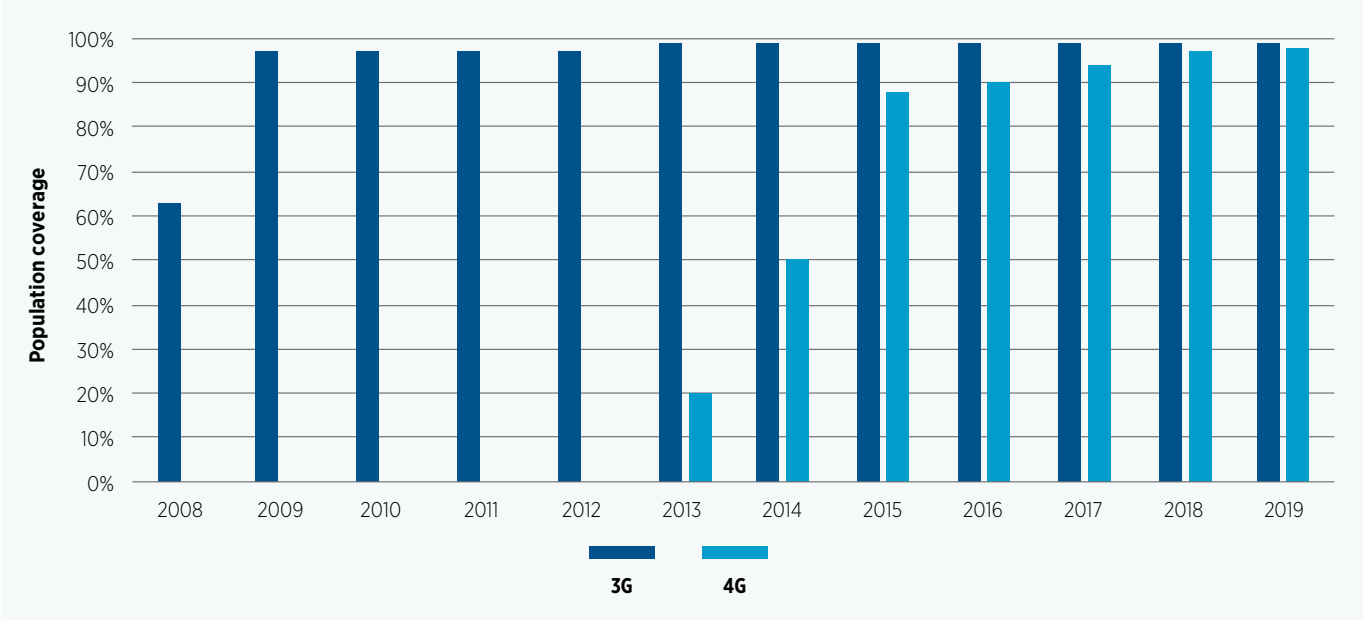
Mobile coverage

2G was first introduced in 1992 in New Zealand. Vodafone was the first to deploy 3G in 2005. By 2013, 3G coverage reached about 98% of the population (Exhibit B.3). 4G deployment reached comparable coverage by 2017. However, only Spark and Vodafone have deployed VoLTE in their 4G networks. The landmass coverage of 4G is slightly under 40%, whereas 3G reaches a landmass coverage of 50% (Vodafone). As such, there is a small proportion of the population (2% to 3%) that is reached by 3G but not by 4G. As at 2019, each of the MNOs in the market had almost ubiquitous 4G population coverage, ranging from 95% to 98%.

EXHIBIT B.3

Source: ITU, Operators, GSMA intelligence

EVOLUTION OF 3G AND 4G COVERAGE IN NEW ZEALAND



In 2017, the New Zealand government announced the second phase of the Rural Broadband Initiative (RBI) and mobile broadband black spot fund (MBSF)[57]. The program will run until 2022 and aims at extending broadband and mobile coverage to rural areas, state highways and tourist locations. MBSF and RBI initiatives rely largely on mobile operators extending 3G/4G coverage to rural and remote areas.

Demand characteristics

As at 2018, the mobile penetration was 135 subscriptions per 100 inhabitants[58]. However, only 82% of New Zealanders are estimated to use smartphones in 2019. Mobile data traffic has been growing exponentially since 2013, reaching about 113PB in 2018 (Exhibit B.4). About half of the subscriptions are prepaid, contributing to about a third of annual mobile traffic. The average data usage per connection (2GB per month) is still low compared to many developed APAC markets such as Australia, Japan and Korea. This can be attributed to many factors, including the relatively high price of higher usage bundles, the widespread availability of high-quality fixed broadband and the easy access to Wi-Fi hotspots.

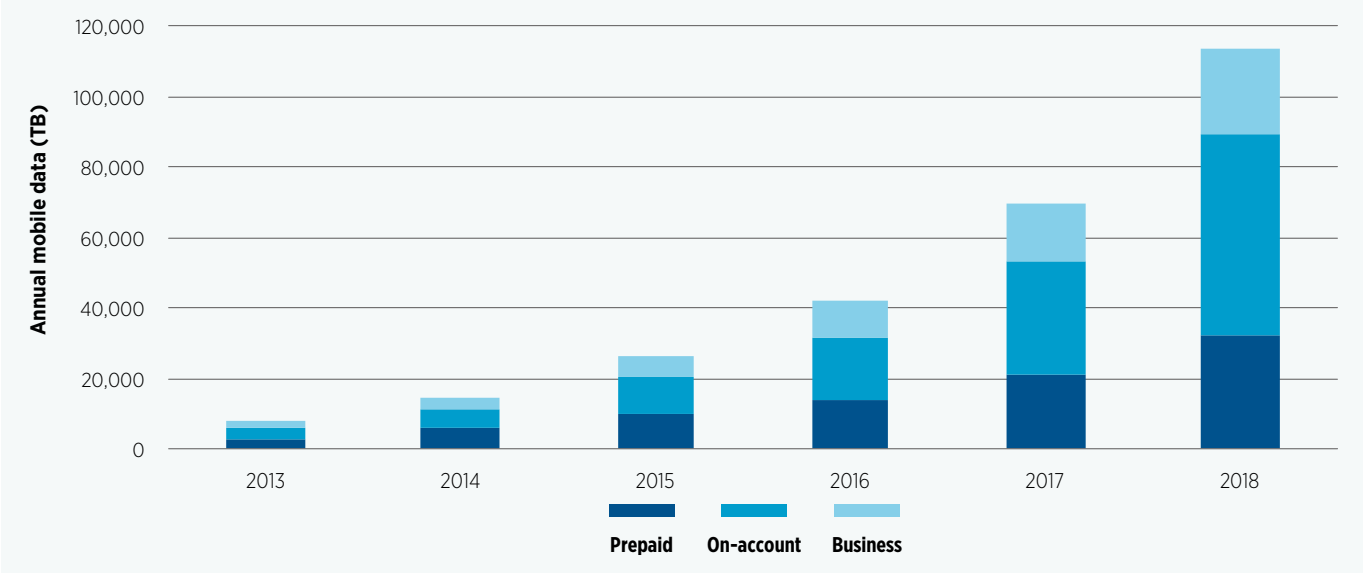
57. Crown Infrastructure Partners (2018). Rural Broadband Initiative phase two (RBI2) and the Mobile Black Spot Fund (MBSF). Fact sheet, Crown Infrastructure Partners, Match 2018. https://www.crowninfrastructure.govt.nz..

58. ITU (2019). ITU World Telecommunications/ICT Indicators database. ITU, 2019.

EXHIBIT B.4

Source: Commerce Commission

ANNUAL MOBILE DATA TRAFFIC IN NEW ZEALAND



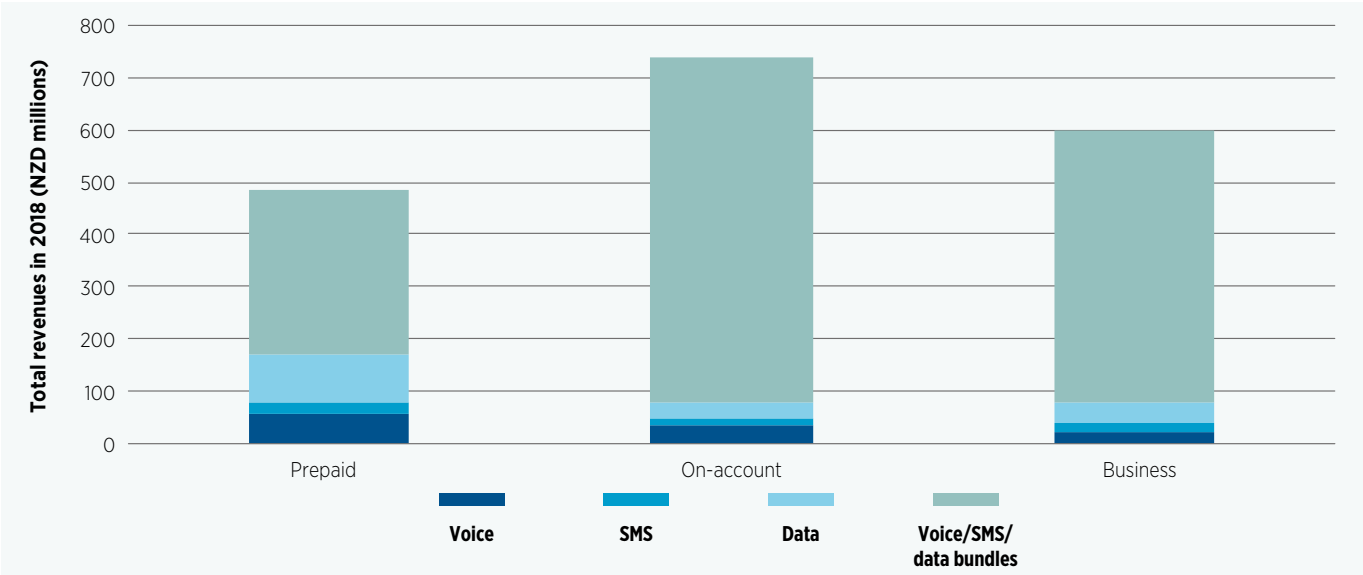
With the rise of mobile data, most subscriptions are for bundles which provide a monthly allowance of minutes, SMS and data.

Overall, data and combined data/voice/SMS bundles accounted for approximately 90% of total mobile revenues in 2018 (Exhibit B.5).

EXHIBIT B.5

Source: Commerce Commission

TOTAL MOBILE REVENUES BY SUBSCRIBER TYPE



MNOs also play an important role in providing fixed wireless broadband connections. The demand for fixed wireless broadband connections increased from 27,000 to 165,000 from 2016 to 2018, comprising around 9% of total fixed broadband connections[59].

59. Commerce Commission (2018). Annual Telecommunications Monitoring Report. Commerce Commission, December 2018.

B.2 Key drivers

Two national operators (Spark and 2degrees) have switched off 2G networks. Both switch-offs were operator initiated in response to strategic plans. In both cases, the regulator (the Commerce Commission) did not intervene or have any involvement in the switch-off process.

Spark

Spark switched off its CDMA based 2G network in July 2012. Spark's 3G network (branded XT Mobile) was launched in May 2009 with 97% 3G population coverage attained in the same year[60]. This gave Spark a period of three years to facilitate the migration of customers to its new 3G network. Prior to 3G launch, Spark recorded a decline in mobile revenues for two consecutive years. This decline was partially attributed to the lack of competitive offering of 2G services, as the main competitor (Vodafone) had already launched a 3G service in 2005. As such, the decision to replace 2G with 3G was market driven and aimed at increasing Spark's share of high-value customers.

The 2G switch-off was publicly announced in June 2010, allowing an official transition period of two years to migrate customers to the new 3G network. To facilitate customer migration, the switch-off process involved:

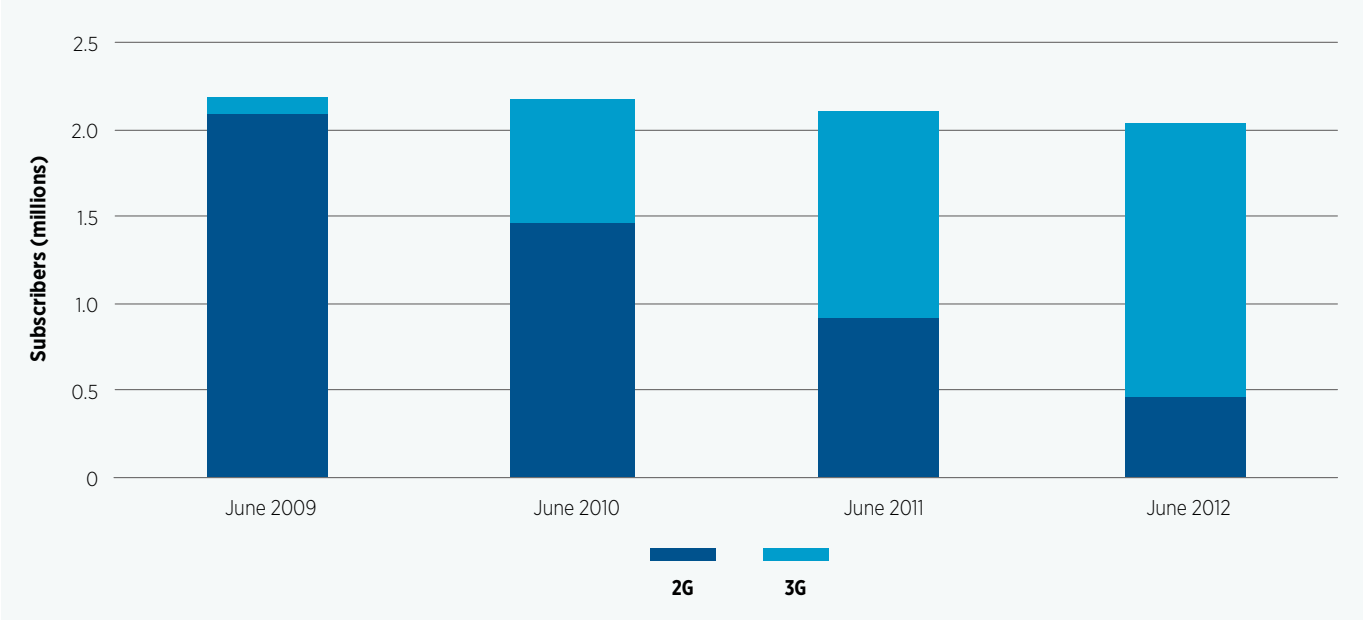
- Sponsoring TV commercials to highlight the benefit of the 3G network;
- Communication with customers via SMS; and
- Promoting a range of 3G tariff plans and a portfolio of smartphone choices.

2G connections fell from about 2 million in 2009 to just under half a million in June 2012 (Exhibit B.6). Spark reported a 3.1% decline in its mobile customer base from 2011 to 2012. This decline was partially attributed to the churn of predominantly low value prepaid customers associated with the 2G closure. As a result, mobile ARPU increased in 2013[61]. The transition period also coincided with the entry of a new mobile operator, 2degrees, which focused initially on the prepaid market segment. The proportion of 2G subscribers that migrated to Spark's 3G network compared to those switching to other operators is unclear. Many of the prepaid 2G connections were simply terminated for being inactive for a long period of time.

EXHIBIT B.6

Source: Spark

THE EVOLUTION OF SPARK'S 2G AND 3G CONNECTIONS DURING THE 2G SWITCH-OFF PROCESS



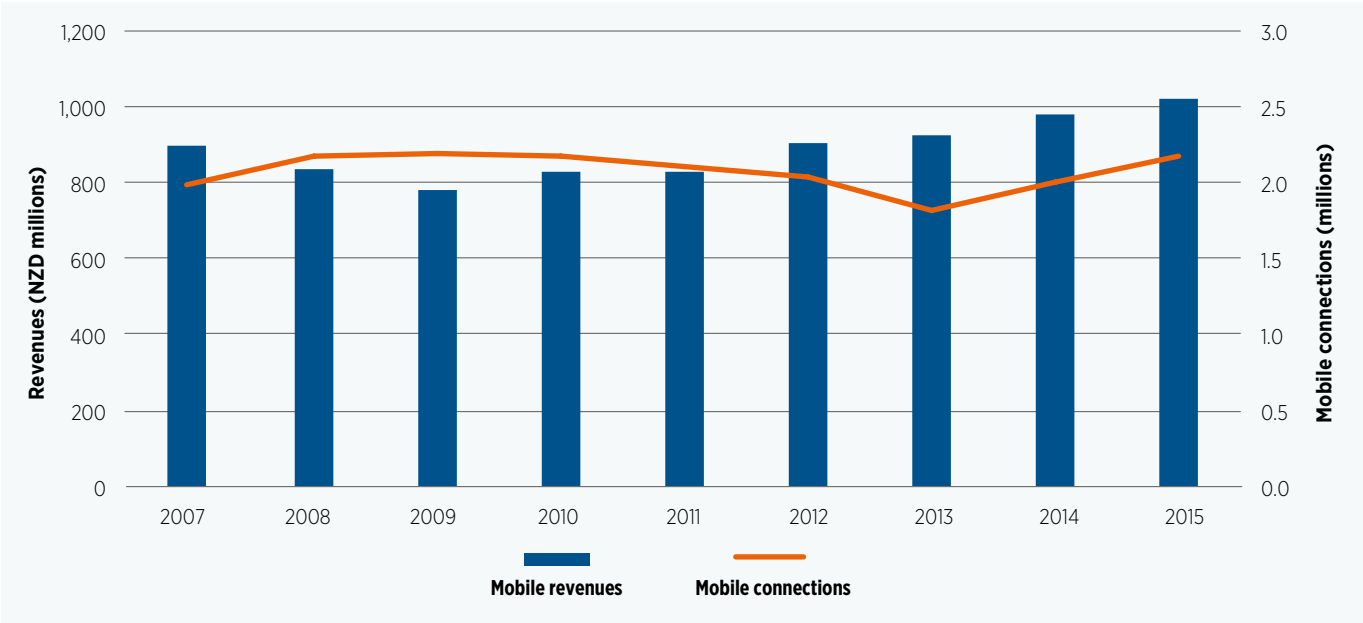
60. Telecom New Zealand (2009). Annual report 2009, Telecom Corporation of New Zealand Limited, June 2009.
61. Telecom New Zealand (2013). Annual report 2013, Telecom Corporation of New Zealand Limited, June 2013.

Prior to the introduction of 3G in 2009, Spark reported declining mobile revenues due to regulatory and competitive pressures, and low ARPU. Despite a notable decline in customers following the closure of 2G in 2012, Spark subsequently reported a steady increase in mobile revenues (Exhibit B.7). This was attributed to increased ARPU, mainly due to the rise of mobile data, an increase in smartphone sales, and acquisition of high-value (post-paid) mobile users[62, 63]. By 2015, Spark had recovered its mobile customer base to levels reported before commencement of the 2G shutdown process.

EXHIBIT B.7

Source: Spark

SPARK'S MOBILE CONNECTIONS AND REVENUES FROM 2007-2015



In June 2009 Spark reported 81,000 low speed M2M connections, likely to be mostly 2G connections as 3G was launched just a few weeks previously. At the time of the 2G switch-off, Spark reported that a small number of specialist data connections using 2G remained active, indicating that special arrangements were necessary with some clients. These specialist connections were completely decommissioned two months after 2G switch-off. The number of M2M connections on the 3G network grew from 2009 to 2012, reaching 229,000 connections at the time of 2G switch-off[64].

At the time of the 3G launch, Spark held only two spectrum licences in the sub-2 GHz bands, 2×15 MHz at 850 MHz and 2×25 MHz at 1,800 MHz, both of which were used by its 2G network. To ensure nationwide coverage, 3G was also launched on the 850 GHz band, alongside the 2G network. Spark's 4G network was initially deployed on the 1,800 GHz band previously used for 2G. As such, the closure of the 2G network enabled Spark to provide more capacity on its 3G and 4G networks.

Spark initiated the RE:MOBILE product stewardship scheme in 2013, aiming at recycling used mobile devices in New Zealand. The company encourages its customers and staff to recycle their handsets by placing dedicated bins in stores and offices. Unusable devices are sent to Japan to be broken down into components. Working devices are sold to businesses that specialise in the re-sale of second-hand mobile devices in other jurisdictions such as Hong Kong, China and Eastern Europe[65]. The scheme, which is endorsed by the government and now supported by all three operators, has collected more a half a million devices since 2014.

62. Spark (2014). Annual Report, Spark New Zealand, June 2014.
63. Spark (2015). Annual Report, Spark New Zealand, June 2015.
64. Telecom New Zealand (2012). Annual report 2012, Telecom Corporation of New Zealand Limited, June 2012.
65. RE::MOBILE. The RE:MOBILE recycling process. Available at www.remobile.org.nz/recycling-process.

2degrees

2degrees commenced operations in New Zealand in August 2009 with the launch of a 2G GSM network in a selected number of urban areas. The commercial operation of its 3G and 4G networks started in July 2010 and June 2014, respectively. In September 2017, the operator announced that it would switch-off its 2G network in March 2018, allowing a migration period of six months[66]. At the time of the announcement, 2degrees' 3G network already covered 98.5% of the population.

To facilitate customer migration, the switch-off process involved:

- ceasing sales of 2G handsets about 18 months before publicly announcing the 2G switch-off to reduce demand, with the switch-off scheduled for 6 months later, being 2 years after ceasing 2G handset sales
- sending SMS and email reminders to customers during the six month formal notice period
- sponsoring TV commercials to attract customers to 3G/4G
- a dedicated website to inform customers about the switch-off process, check their device compatibility and the range of available offers
- promoting discounted smartphone devices for both prepaid and postpaid customers
- encouraging customers to recycle old handsets by offering discounted smartphones in return.

2degrees ceased selling 2G-only handsets about 18 months before announcing the shutdown. This was intended to enable customers to migrate to smartphones offering a richer data service experience and to avoid disruption to customers. 2degrees did not report the number of remaining 2G customers at the time of switch-off, however the operator indicated that the number of 2G connections declined to reasonably low levels before the switch-off. 2degrees noted that the number of 2G M2M connections was not significant. There were no largescale agreements, such as with utility companies, to provide M2M connectivity.

In discussions with 2degrees, the ability to meet increasing customer demand for data services and spectrum efficiency were highlighted as the main drivers for the 2G switch-off. Prior to the switch-off, both the 2G and 3G networks used the 900MHz and the 1800MHz bands[67], whereas 4G was deployed in the 700MHz band (Exhibit B.8). After the 2G switch-off, the spectrum was refarmed for 4G services[68].

EXHIBIT B.8

Source: Trilogy International Partners Inc 69

2DEGREES SPECTRUM USAGE BEFORE AND AFTER 2G SWITCH-OFF

Band (MHz)	Spectrum (MHz)	Spectrum usage prior to 2G switch-off	Spectrum usage after 2G switch-off
700	2 × 10	4G	4G
900	2 × 9.8	2G and 3G	3G and 4G
1800	2 × 25	2G and 3G	4G
2100	2 × 15	3G	3G

66. 2degrees (2017). 2degrees to close down 2G access in March 2018. 2degrees press release, September 2017. Available at https://www.2degreesmobile.co.nz/company/news-and-media-releases/2degrees-to-close-down-2g-access-in-march-2018/.
67. Trilogy International Partners (2018). Annual Information Form, Trilogy International Partners, March 2018.
68. Trilogy International Partners (2019). Annual Information Form, Trilogy International Partners, March 2019.
69. Trilogy International Partners is the primary shareholder of 2degrees.

2degrees indicated that the released spectrum enabled 2degrees to deploy 4G at a lower cost than in the 700MHz band, as it only involved software and smaller hardware upgrades to the existing 3G network. 2degrees has not announced plans to switch off the 3G network. As VoLTE has not been deployed in the 4G network, 2degrees is still reliant on 3G to handle voice calls. In a discussion with 2degrees, the penetration and costs of VoLTE enabled smartphones were highlighted as important factors to be considered when deciding to switch-off 3G.

Vodafone

Vodafone launched its 2G network in 1998 and it has been the first to deploy 3G and 4G in 2005 and 2013, respectively. Vodafone is still operating all three technologies simultaneously, providing ubiquitous coverage. While Vodafone has not determined a firm date yet, it has publicly indicated that it intends to switch off its 2G network in 2025[70].

In 2010, a major electricity and gas distributor in New Zealand, Vector, selected Vodafone's 2G/GPRS network to connect about one million smart meters nationwide[71]. These devices typically have a lifetime of at least 15 years. In an interview, Vodafone staff indicated that the agreement with Vector is a major driver for maintaining the 2G network despite declining voice traffic. However, it has already communicated to Vector its intention to switch off 2G in 2025. Vodafone maintains a total of 1.6 million IoT and M2M connections in New Zealand, including 2G, 3G and 4G connections. Cellular IoT based on 2G is still offered by Vodafone[72]. The 2G service operates nationwide on the 900 MHz band. Due to declining voice traffic, the 2G network was rationalised in terms of capacity to meet M2M demand which remains relatively stable over time. The released 2G spectrum was re-used by 3G and 4G. Vodafone's licence for the 900 MHz band expires in 2031.

Vodafone has not publicly confirmed the date to switch-off 3G yet. However, interviewed staff indicated that 3G is likely to be switched off prior to 2G, possibly between 2023 and 2025. The drivers for switch-off would be mainly cost reduction and frequency reuse. Key factors Vodafone will consider before switching off 3G include:

- The penetration of VoLTE enabled devices among customers;
- The level of demand on the 3G network; and
- 4G coverage.

While Vodafone has already launched VoLTE, 4G coverage still lags slightly behind 3G. By 2021, 4G coverage is expected to match that of 3G. Vodafone also indicated that 3G roaming is an important revenue stream that must be taken into account. The 3G network also supports a substantial number of fixed wireless broadband connections in rural areas. However, Vodafone indicated that these connections are being gradually migrated to 4G.

70. Vodafone (2016). Vodafone signals the end is nigh for its 2G voice service. Press release, March 2016. Available at https://www.stuff.co.nz/business/industries/77907677/vodafone-signals-the-end-is-nigh-for-its-2g-voice-service.
71. Vodafone (2010). AMS chooses Vodafone's network for smart metering. Case study, Vodafone, 2010. Available at https://www.vodafone.co.nz/a/pdfs/corporate-and-government/ams_case_study.pdf
72. Vodafone. Internet of Things (IoT). Available at https://www.vodafone.co.nz/iot/.

B.3 Process

The switch-off of 2G networks in New Zealand was completely market driven, with no regulator involvement. A summary of the key factors associated with the switch-off process is depicted in Exhibit B.9.

EXHIBIT B.9

Source: operators

SUMMARY OF 2G SWITCH-OFF PROCESS IN NEW ZEALAND

	Spark	2degrees	Vodafone
2G switch-off date	July 2012	March 2018	2025
Transition period	2-3 years	2-3 years	n.a.
Time from public announcement to switch-off	2 years	6 months	~ 9 years
3G/4G coverage at switch-off date	97%	98.5%[73]	n.a.
Percentage of 2G connections at time of switch-off	~ 24% (mostly prepaid)	n.a.	n.a.
Percentage of 2G M2M connections at time of switch-off	~ 26%	n.a.	n.a.
Drivers for switch-off	Frequency re-use	Frequency re-use	n.a.
Regulatory challenges	None	None	n.a.
Business challenges	None	None	Agreement to support large number of M2M connections
Process facilitation	TV campaign on 3G benefits Regular SMS reminders to customers Advertising a range of 3G plans and smartphones Decommissioning of M2M connections delayed for three months	Cessation of 2G handset sales about three years earlier Regular SMS reminders to customers Assistance in identifying handsets needing upgrade Advertising a range of plans and smartphones Working directly with M2M customers	Cessation of 2G handset sales Rationalisation of 2G network capacity
Released 2G spectrum	Reused for 3G and 4G	Reused for 4G	2G spectrum already rationalised and reused by 3G and 4G
2G handsets	Voluntary handset recycling instore using the RE:MOBILE scheme	Voluntary handset recycling instore using the RE:MOBILE scheme	Voluntary handset recycling instore using the RE:MOBILE scheme
3G phase out date	Not announced	Not announced	2023-2025

Market drivers included optimising infrastructure and spectrum resources by focusing on high-value services, and declining demand for 2G. The time between public announcement and switch-off ranged from six months (2degrees) to two years (Spark). However, at the time Spark announced 2G shutdown smartphones and 3G services were still at their early stages. Thus, setting a long transition period is essential to allow higher smartphone penetration and for customers to embrace new services. In the case of 2degrees, a longer formal notice period was less pressing, as smartphone penetration was already high. Nevertheless, the company began preparing for the switch-off about three years prior to the public announcement. One operator, Vodafone, has announced that it will not switch-off 2G until 2025. The decision is mainly influenced by an agreement with a utility company to support about a million 2G M2M connections until that date.

Both operators already had nationwide 3G/4G coverage at least three years before the 2G switch-off took place. To facilitate customer migration, the operators relied solely on marketing campaigns. While both Spark and 2degrees indicated that they had to make special arrangements or work directly with a small number of M2M customers, no pressing issues were reported. The number of M2M connections was relatively small compared to the overall 2G subscriber numbers, with no reports of large-scale service agreements for either operator.

73. About 2% of 2degrees' coverage is achieved by a roaming agreement with Vodafone.

Annex C: Japan: 2G switch-off

Japan was the earliest market to experience 2G switch-off, with the first occurring in 2008, and complete switch-off of 2G services by all three operators by 2012. The switch-off process was initiated by the regulator after requests from operators.

C.1 Mobile market

Regulation

The provision of telecommunications services in Japan is mandated by the Telecommunication Business Act (the Telecom Act), the Radio Act and the Wire Telecommunications Act, and it is administered by the Ministry of Internal Affairs and Communications (MIC). The purpose of the Radio Act is to promote the public welfare by ensuring the fair and efficient usage of radio waves. Under the Radio Act spectrum use is allocated by the MIC.

The telecommunications market was fully liberalised in 1985, ending the monopoly of the newly privatised Nippon Telegraph and Telephone Public Corporation (NTT).

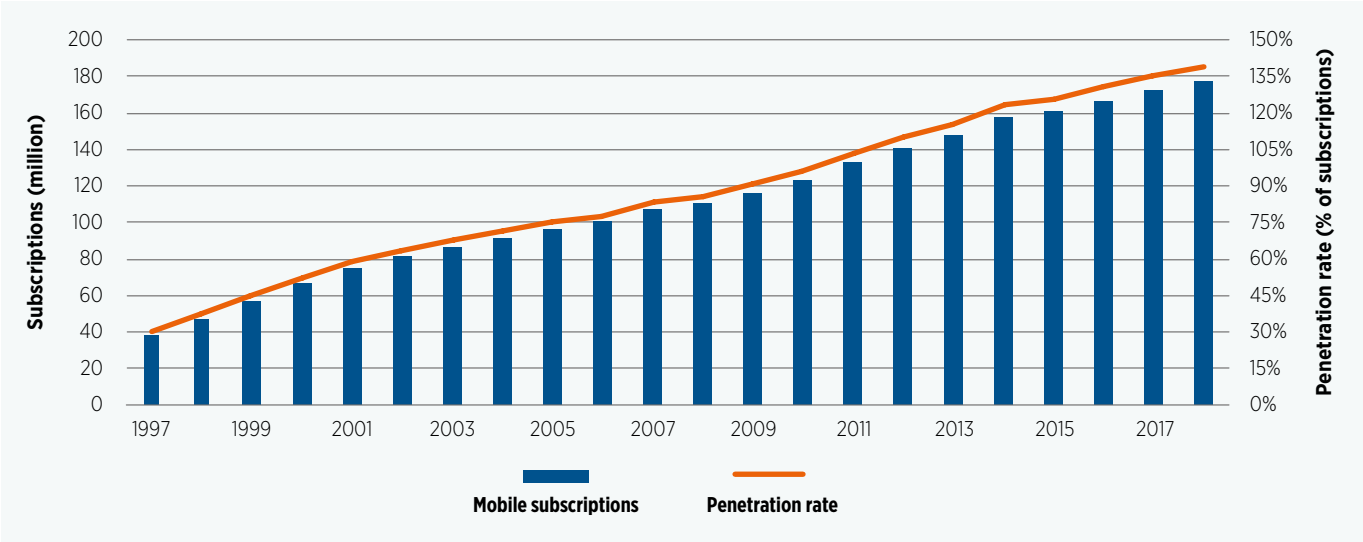
Market

As at September 2019 mobile subscriptions in Japan totalled 178.41 million.[74] MVNO subscriptions represented around 12% of the total as at March 2019.[75] Since 1997 the number of mobile subscribers has experienced average annual growth of 7.6% (CAGR), with penetration increasing from 30% in 1997 to 139% in 2018 (Exhibit C.1).

EXHIBIT C.1

Source: ITU

MOBILE SUBSCRIPTIONS AND PENETRATION RATE, JAPAN, 1997 TO 2018



3G networks provide coverage to 99.9% of inhabitants, while 4G coverage is slightly lower reaching 99% of population.[76]

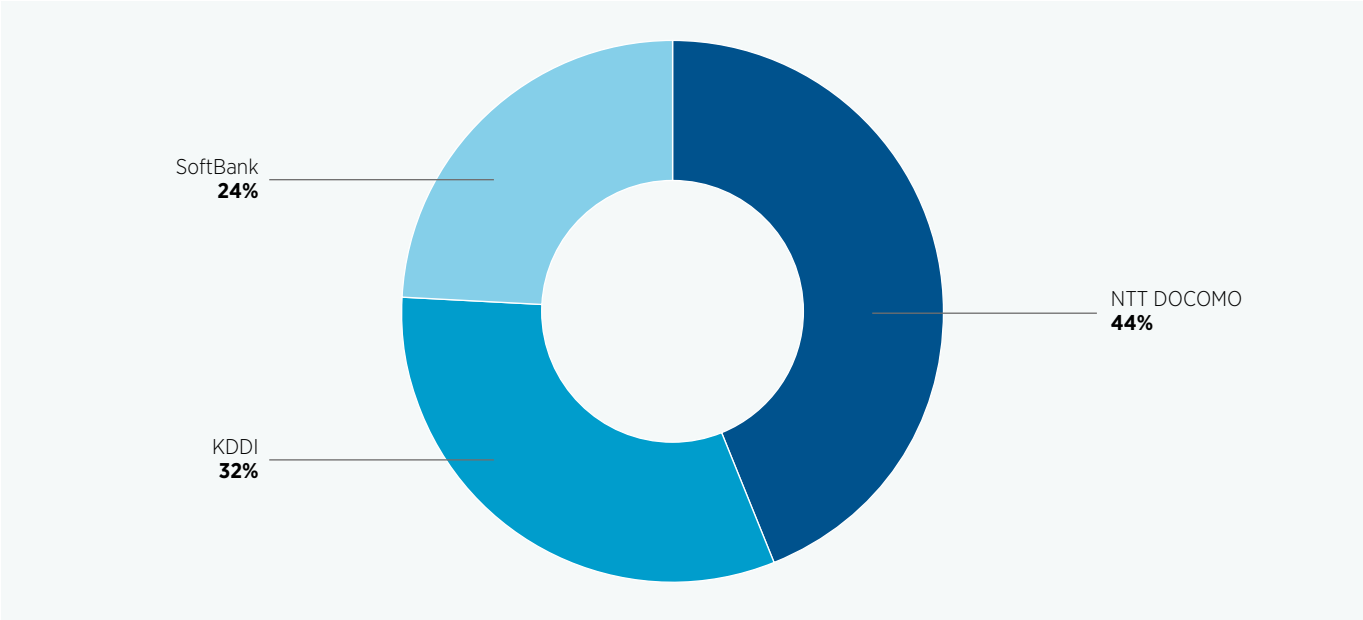
74. TCA (2019), Number of subscribers by Carriers. Available at https://www.tca.or.jp/english/database/index.html
75. KDDI (2019), Integrated report 2019, June 2019. Page 48. Available at https://www.kddi.com/english/corporate/ir/ir-library/annual-report/.
76. ITU (2019), ICT Indicators (WTI) Database 2019.

The Japanese mobile market is dominated by three MNOs. NTT DOCOMO is the largest operator with 44% market share, followed by KDDI and SoftBank, with 32% and 24% market share respectively (Exhibit C.2).

EXHIBIT C.2

Source: Telecommunica-tions Carriers Association

MOBILE MARKET SHARE, JAPAN, JUNE 2019



In 2018 the MVNO Rakuten Mobile was given approval by the regulator to enter the MNO business, and has deployed an LTE network in urban areas, including Tokyo, Nagoya and Osaka, with coverage beyond those areas delivered via a roaming agreement with KDDI. The company opened applications to 5,000 subscribers free of charge to ensure the stability and quality of its service and to continue improving the network based on customer feedback and requests. According to public statements the official launch of the service will occur prior to 31 March 2020.[77]

Spectrum holdings

In 2004 MIC announced a re-organisation of the 800 MHz band, which was being used by NTT DOCOMO and KDDI for both 2G and 3G services. The release of spectrum through switch-off of the 2G networks facilitated the refarming process, enabling MIC to reduce band fragmentation before reassigning frequencies to the operators.

3G and 4G services are provided over the 800 MHz, 900 MHz and 2.1 GHz bands. For 4G services operators also use the 1.5 GHz, 1.7 GHz, 2.6 GHz and 3.5 GHz bands. NTT DOCOMO and SoftBank have the most spectrum allocated for 3G and 4G services – 240 MHz and 220 MHz, respectively. KDDI uses 190 MHz for 3G and 4G services and Rakuten was assigned only 40 MHz for 4G (Exhibit C.3).

In April 2019 the MIC allocated spectrum in the 3.7 GHz, 4.5 GHz and 28 GHz bands for 5G services. Both NTT DOCOMO and KDDI received 600 MHz, with 500 MHz assigned to SoftBank and Rakuten (Exhibit C.3 and Exhibit C.4)

77. Rakuten (2019), Rakuten Mobile to Launch New Mobile Operator Service, press release, 6 September 2019. Available at https://global.rakuten.com/corp/news/press/2019/0906_02.html.

EXHIBIT C.3

Source: KDDI

SPECTRUM HOLDINGS AS OF APRIL 2019, JAPAN

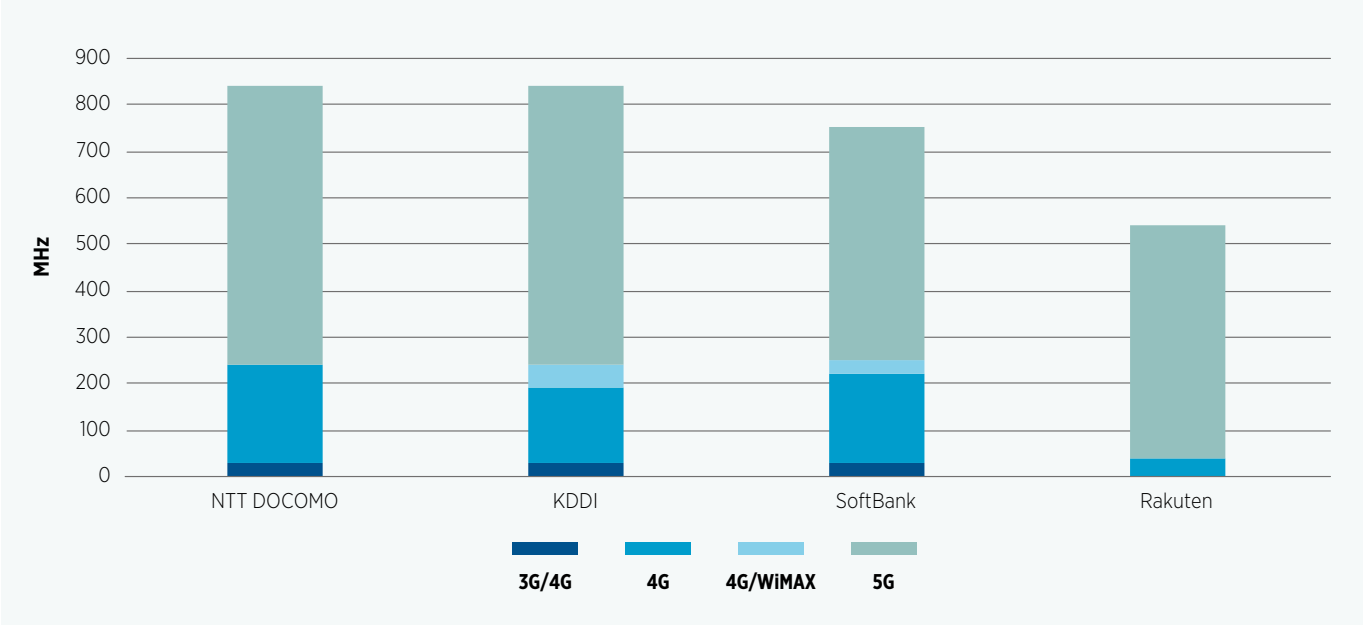
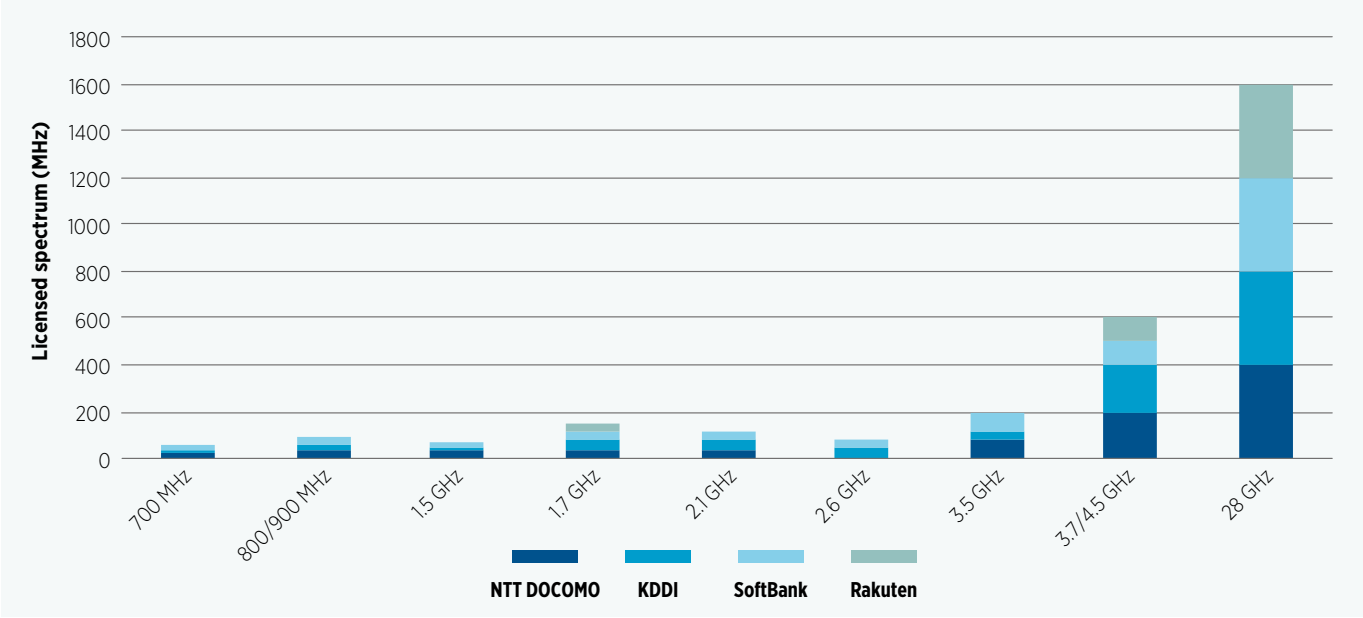


EXHIBIT C.4

Source: KDDI

SPECTRUM HOLDINGS BY FREQUENCY FOR JAPAN MNOs, AS AT APRIL 2019



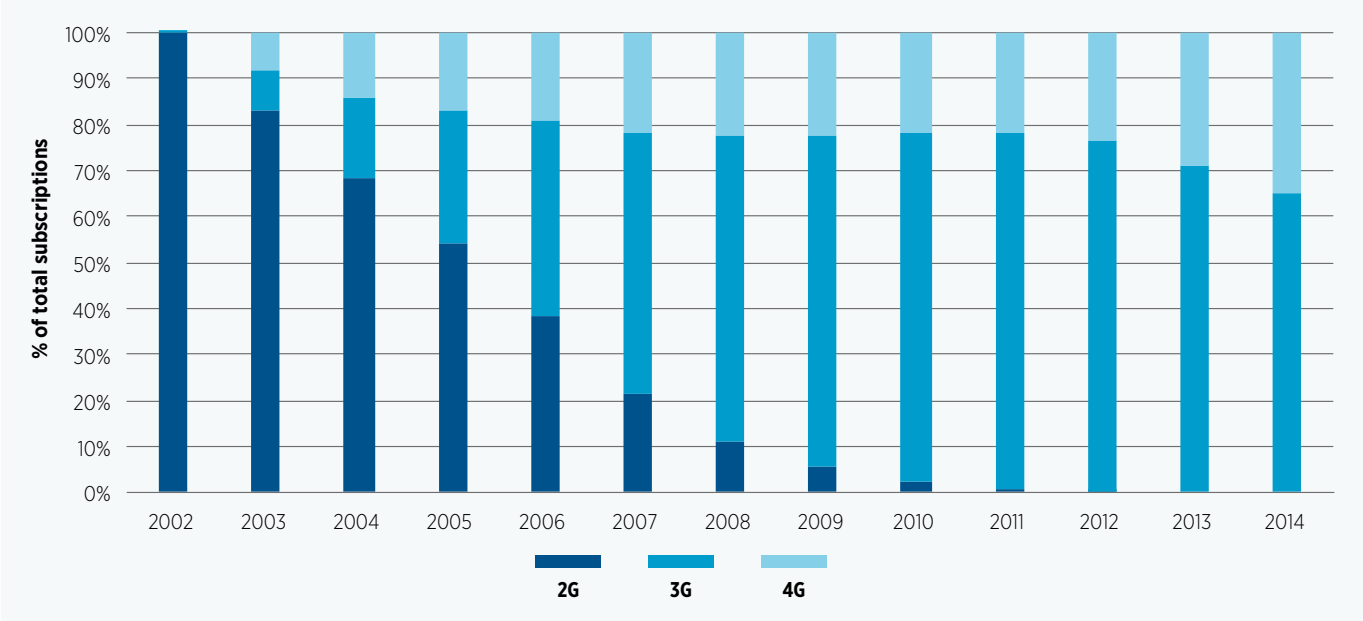
C.2 Key drivers

By 2012 Japan's three MNOs terminated 2G services, making Japan the first market to move to a full 3G / 4G service scheme. In 2012, when the shutdown took place, 2G subscriptions amounted for less than 0.05% of total subscriptions (Exhibit C.5).

EXHIBIT C:5

Source: NTT DOCOMO

SUBSCRIPTIONS BY TECHNOLOGY FOR TOTAL MARKET, 2002 TO 2014



It should be noted that the PDC technology deployed by all three operators in 2G networks was a standard only used in Japan, although KDDI also operated a 2G cdmaOne (IS-95) network. Options for 2G roaming were therefore limited to the KDDI cdmaOne network.

KDDI

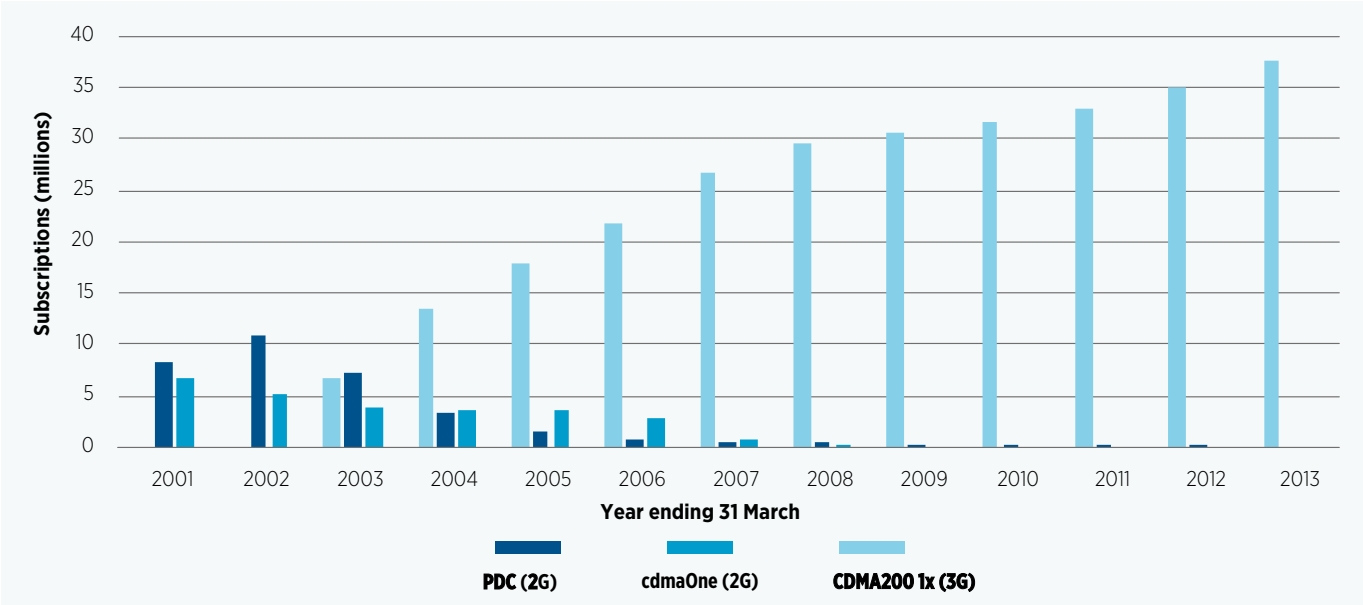
KDDI was the first operator in Japan to take a step towards 2G switch-off when, in December 2006, it announced that TU-KA 2G services, which used a PDC network, would be terminated in March 2008.[78] At the time of switch-off there were 234,100 subscriptions remaining. A second 2G network, based on cdmaOne, continued until mid 2012 – by March 2012 subscriptions had dwindled to just over 50,000 (Exhibit C.6).

78. KDDI (2006), Cessation of Cellular "TU-KA" Service by Parent KDDI Japan in March 2008, media release, 7 December 2006. Available at https://www.kddi.com/english/corporate/news_release/2006/1207/.

EXHIBIT C:6

Source: KDDI

KDDI MOBILE SUBSCRIBERS BY TECHNOLOGY, 2001 TO 2013



From October 2005 fees for TU-KA 2G customers migrating to a 3G service had been waived. Prior to this, customers wishing to retain their numbers were charged JPY2835 (including tax).[79]

SoftBank

To accelerate migration from 2G to 3G services, SoftBank announced that no new applications for 2G subscriptions would be accepted after March 2008. Prepaid plans for 3G – previously only available on the 2G service – were launched in February 2008.[80]

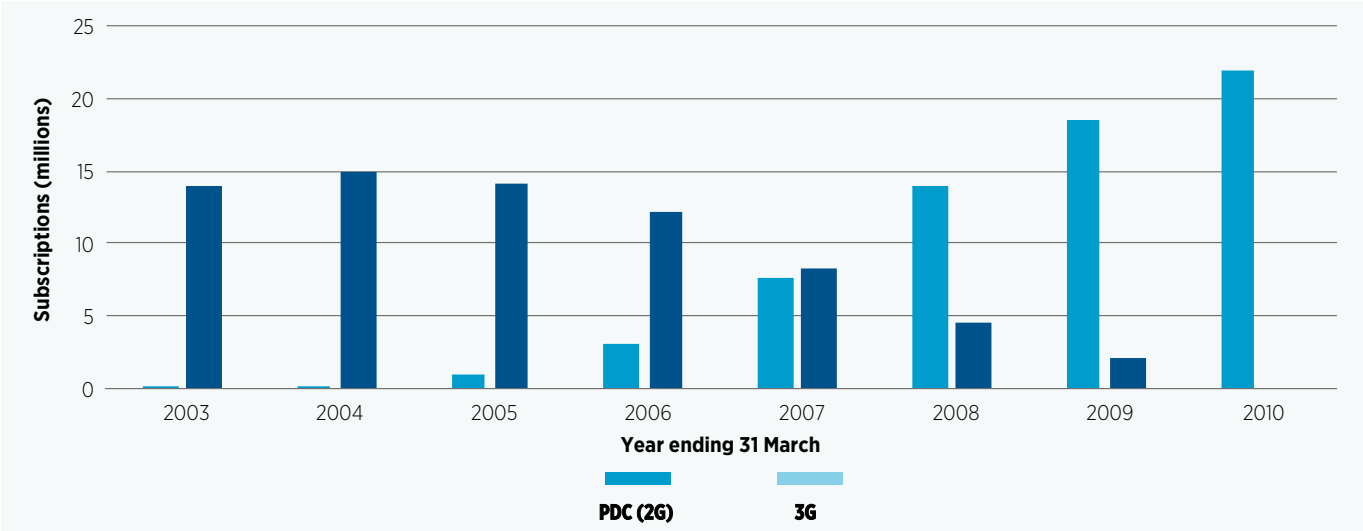
Termination of the 2G network was announced in July 2008 with the network to be closed in March 2010.[81] By that time 2G subscriptions were less than a quarter of SoftBank's total (Exhibit C.7). SoftBank's stated aim was to promote migration to 3G services. During the migration process, which lasted almost two years, 2G subscribers received information through direct mail and at SoftBank retail shops.

79. KDDI (2006), Cessation of Cellular "TU-KA" Service by Parent KDDI Japan in March 2008, media release, 7 December 2006.
80. SoftBank (2007), Cut-off on New Applications for 2G Mobile Service, media release, 14 December 2007. Available at https://www.softbank.jp/en/corp/group/sbm/news/press/2007/20071214_01/.
81. SoftBank (2008), Discontinuation of 2G Service, media release, 3 July 2008. Available at https://www.softbank.jp/en/corp/group/sbm/news/press/2008/20080703_01/.

EXHIBIT C:7

Source: SoftBank

SOFTBANK MOBILE SUBSCRIPTIONS BY TECHNOLOGY, 2003 TO 2010



NTT DOCOMO

In January 2009 NTT DOCOMO announced that its 2G services would be discontinued at the end of March 2012.[82] Migration to 3G services had accelerated from 2004, and by March 2009 2G subscriptions had declined to just over 10% of the operator's customer base (Exhibit C.8). NTT DOCOMO's 2G network was based on the Japanese PDC technology.

Key drivers for the switch-off included:

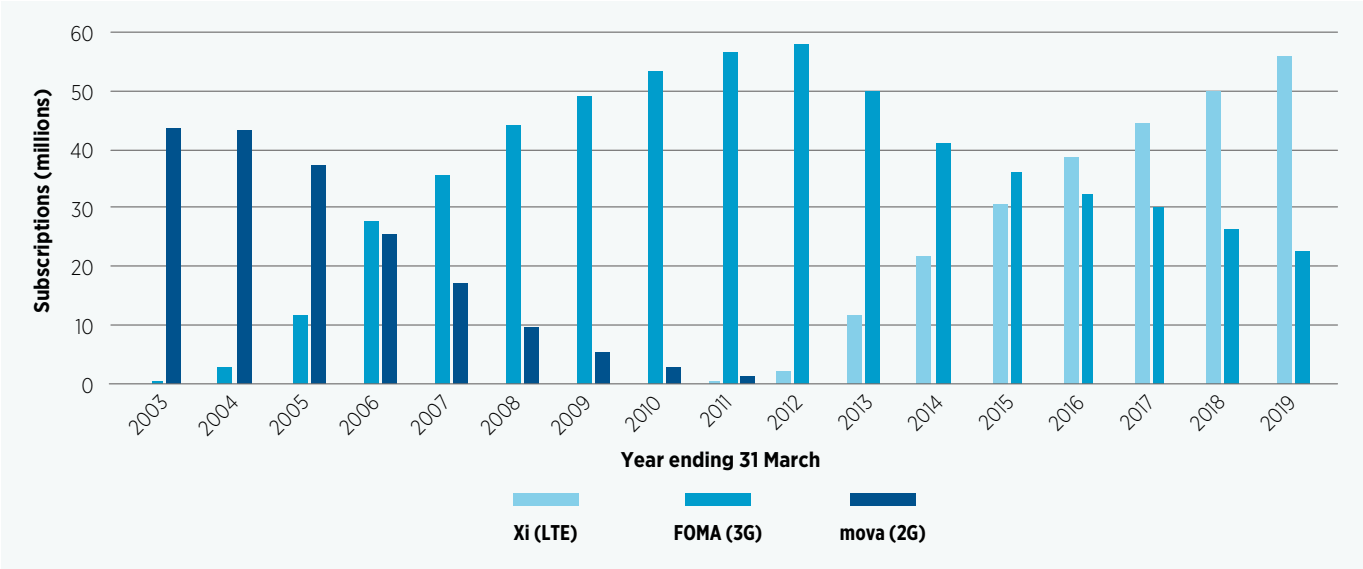
- The desire to harmonise the frequency band plan for 850 MHz with those of other markets;
- To improve efficiency in spectrum usage of the 850 MHz and 1.5 GHz bands with less fragmented spectrum assignment; and
- To enable efficient introduction of 3G technology to support improved user experience.

Cost savings were achieved through the switch-off with the harmonised band plan and a reduction in opex.

EXHIBIT C:8

Source: NTT DOCOMO

NTT DOCOMO SUBSCRIPTIONS BY TECHNOLOGY, 2003 TO 2019



82. NTT DOCOMO (2009), DOCOMO to Terminate mova and DoPa 2G Services, media release, 30 January 2009. Available at https://www.nttdocomo.co.jp/english/info/media_center/pr/2009/001428.html.

NTT DOCOMO originally scheduled the 2G switch-off for December 2012[83], however the date was brought forward to March 2012. The operator ceased connecting new 2G subscriptions in November 2008. Ultimately all 2G services were substituted and supported by the new 3G technology and networks.

Customers who wished to migrate to 3G services were offered discounts on the cost of purchasing 3G handsets and related administrative fees were waived. There is a program to of recycling initiatives, including the collection of used mobile phones and batteries.

Note that there was a regulatory condition regarding the termination date of the spectrum use for 2G in Japan and the switch-off was conducted accordingly. As spectrum licences were not technology-neutral, new licences were required for 3G technology using the refarmed spectrum.

In late 2019, NTT DOCOMO announced that it will be switching off its 3G service in March 2026.[84] The operator noted that its 3G subscriber base is declining as customers migrate to 4G (Exhibit C.8) and that teminating the service will enable resources to be concentrated on 5G.

C.3 Process

The 2G switch-off schedules in Japan were initiated by the MNOs, with each selecting the most appropriate timing given individual circumstances. Frequencies that had been assigned to each of the operators for 2G were utilised continuously as these were reused for 3G services. The regulator's role was to ensure the adoption of adequate consumer protection measures. Accordingly, operators were requested to make appropriate announcements to the public on the timing of 2G service cessation. Operators initiated marketing campaigns and provided incentives to consumers to upgrade services.

With strategies to focus investment on 4G and 5G technologies, the three Japanese MNOs have already publicly announced termination schedules for 3G as follows:

- KDDI: March 2022[85];
- Softbank: January 2024[86]; and
- NTT DOCOMO: March 2026.[87]

83. CommsUpdate (2009), DOCOMO brings forward 2G shutdown; confirms end-2010 LTE date, https://www.commsupdate.com/articles/2009/11/18/docomo-brings-forward-2g-shutdown-confirms-end-2010-lte-date/.
84. NTT DOCOMO (2019), Termination of FOMA and i-mode services, press release, 29 October 2019. Available at https://www.nttdocomo.co.jp/info/news_release/2019/10/29_00.html.
85. KDDI (2018), KDDI to End CDMA 1X WIN Service, 16 November 2018. Available at https://news.kddi.com/kddi/corporate/english/newsrelease/2018/11/16/3505.html
86. Sofbank (2019), Discontinuation of 3G Services, 6 December 2019. Available at https://www.softbank.jp/en/corp/news/press/sbkk/2019/20191206_03/
87. NTT DOCOMO (2019), Message from the CEO, October 2019. Available at https://www.nttdocomo.co.jp/english/corporate/ir/management/message/index.html

Annex D: Singapore: 2G switch-off

All three MNOs switched off 2G networks in Singapore in 2017 in a process initiated by the MNOs, but approved and supported by the regulator.

D.1 Mobile market

Regulation

The telecommunications sector in Singapore is regulated by the Info-communications Media Development Authority (IMDA)[88]. The IMDA is responsible for spectrum allocation, management and monitoring. It specifies the terms and conditions associated with spectrum licences (awarded via auctions or administratively), as well as licences to provide telecommunications services in Singapore. Equipment type approval is also the responsibility of IMDA.

Market

Since telecommunications market deregulation in 2000, Singapore has experienced considerable growth in competition and technological innovation. There are now more than ten companies providing mobile services, including MNOs and MVNOs. The market is dominated by three MNOs – Singtel Mobile, StarHub Mobile and M1. The Australian company TPG Telecom is the fourth operator, with a licence granted in December 2016.

Mobile revenues have been decreasing mainly due to the aggressive competition for gaining market. Starhub mobile revenues has been declining annually since 2015 – for the year ended in December 2018, the company reported an 8.2% annual decrease in mobile services revenue.[89] Singtel's mobile revenue fell 3.3% in the financial year ended in March 2018,[90] and 3,8% in 2019.[91] Intense price competition, lower voice revenues and increased number of SIM-only plans are cited by both operators as the main drivers for mobile revenue decrease.

Having switched off 2G completely in 2018, Singapore's 3G and 4G mobile networks cover 100% of the population, with a penetration rate of 154% as at June 2019. 3G services were rolled out in 2005 and 4G in 2013. Since the launch of 4G services the number of 3G subscribers decreased annually at the rate of 16.5% (CAGR) – currently 4G represents more than 80% of total mobile subscriptions (Exhibit D.1).

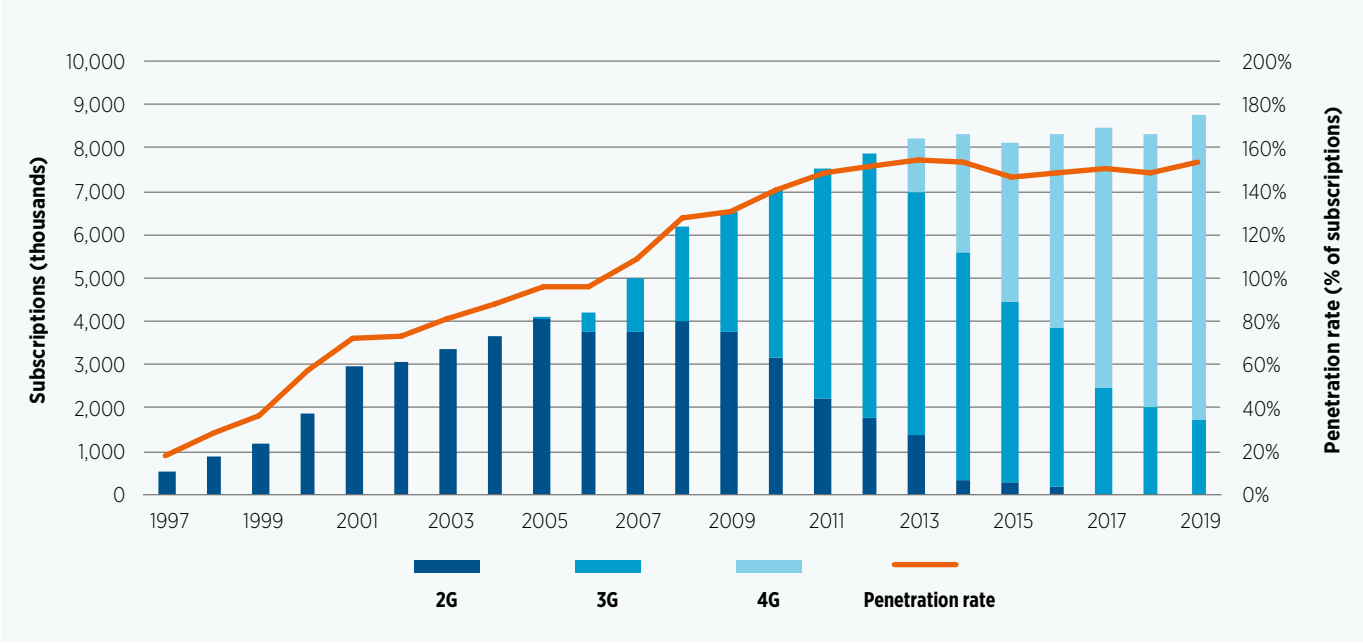
It is notable that Singapore's mobile broadband traffic density (per urban km2) is one of the highest in the world, indicating both high customer and networking infrastructure density.

88. Formerly Infocomm Development Authority (IDA) in 2015.
89. Starhub (2019), Annual Report 2018, March 2019. Page 94.
90. Singtel (2018), Annual Report 2018. Page 122.
91. Singtel (2019), Annual Report 2019. Page 144

EXHIBIT D:1

Source: IMDA

MOBILE SUBSCRIPTIONS AND PENETRATION RATE, SINGAPORE, 1997 TO 2019



Voice over LTE (VoLTE) services have been available in Singapore since 2013 – currently the four MNOs have networks capable of providing VoLTE. By 2014 StarHub and Singtel were the first two MNOs providing VoLTE, with M1's network being upgraded the following year to support VoLTE.

Spectrum holdings

IMDA has released spectrum in the following frequency bands for the provision of public mobile services:

- 700 MHz Frequency Division Duplex (FDD)
- 900 MHz (FDD)
- 1,800 MHz (FDD)
- 1,900 MHz Time Division Duplex (TDD)
- 2,100 MHz (FDD)
- 2.3 GHz TDD
- 2.5 GHz (FDD and TDD)

Currently Singtel has the largest amount of spectrum, followed by StarHub, M1 and TPG, respectively. TPG, holding spectrum in the 900 MHz and 2.5 GHz, is the only MNO with no spectrum allocated for 3G services (Exhibit D.2 and Exhibit D.3).

EXHIBIT D:2

Source: IMDA

SPECTRUM HOLDINGS AS OF 2020, SINGAPORE

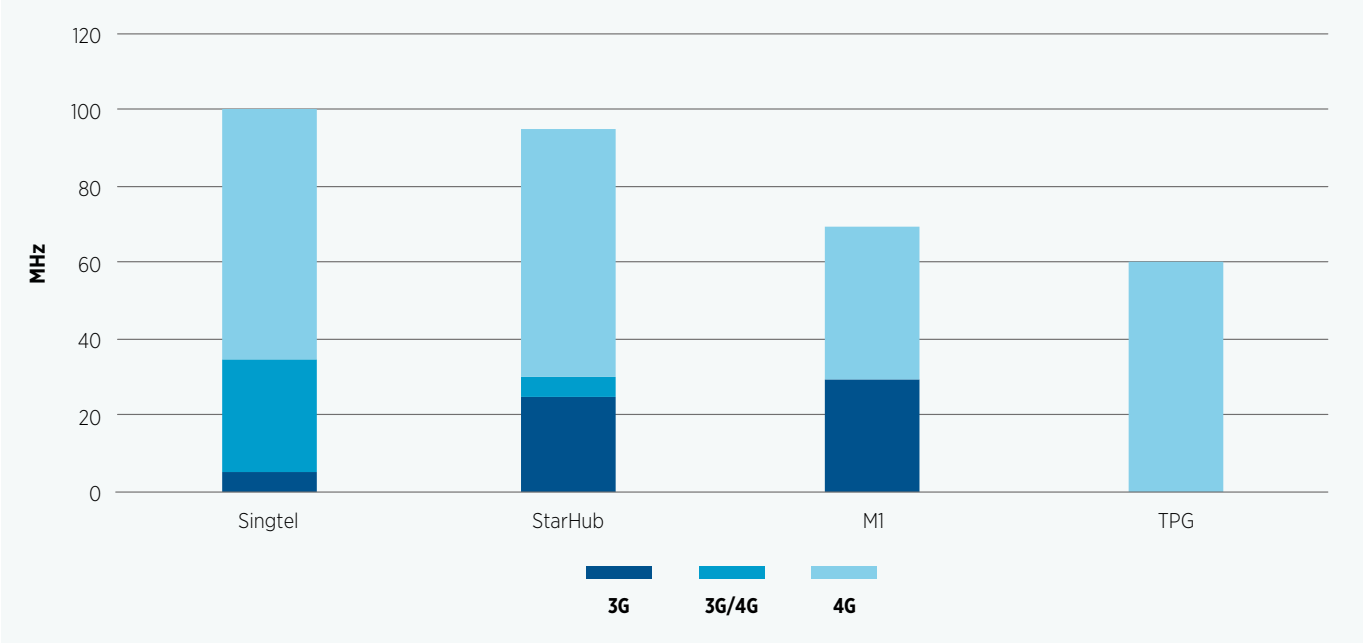
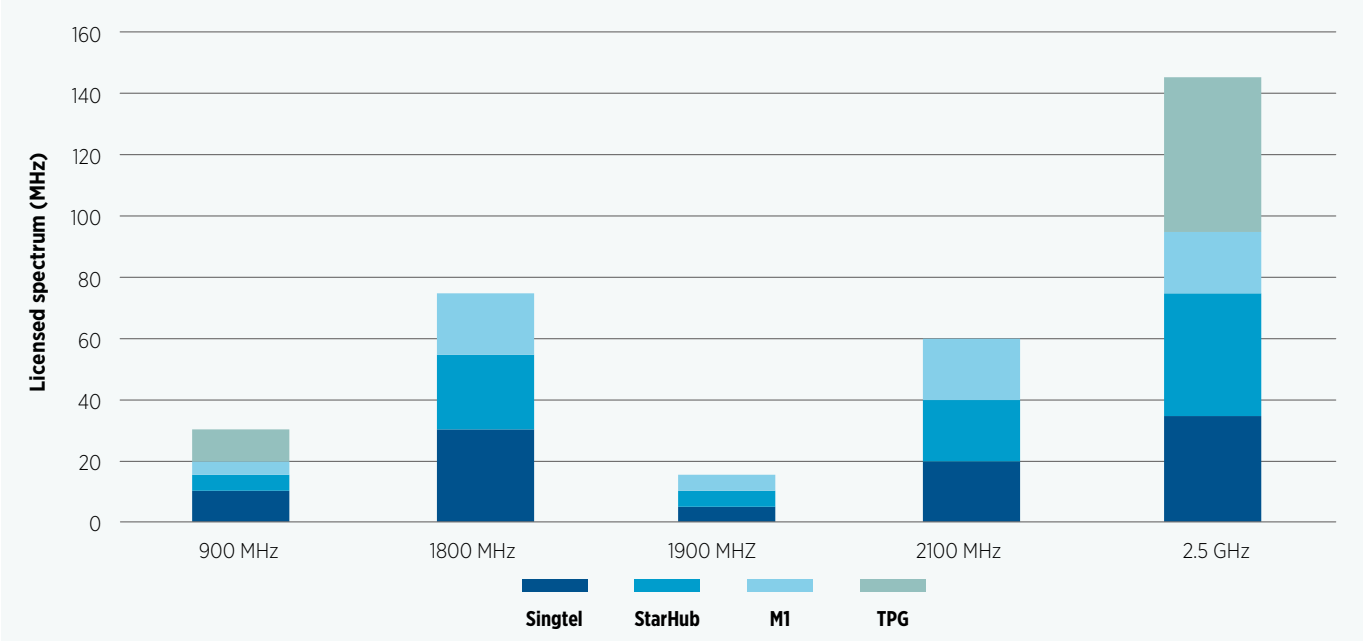


EXHIBIT D:3

Source: IMDA

SPECTRUM HOLDINGS BY FREQUENCY FOR SINGAPORE MNOS, AS OF 2020



D.2 Key drivers

In 2015, IMDA approved the request of the MNOs (M1, Singtel Mobile and StarHub Mobile) to switch-off their 2G networks with effect from 1 April 2017.

Spectrum rights granted in Singapore are not technology neutral therefore MNOs required permission from IMDA to cease 2G services and to reuse that spectrum for services using other technologies such as 3G or 4G. Spectrum rights grant their owners the right to use specific frequency bands, and set out the requirements and terms and conditions of use which for the case of Singapore includes the type of technology.[92]

With spectrum rights for 2G expiring on 31 March 2017, MNOs viewed this as an opportune time to switch off the 2G networks enabling the spectrum to be refarmed for a more efficient use (higher bandwidth services).

StarHub's major driver for 2G cessation was freeing up spectrum for deploying 4G services. As early as 2014 StarHub started planning 2G switch-off due to declining demand and high uptake of 3G. As claimed during our interview with StarHub, equipment vendors and suppliers did not play any role in StarHub's decision, nor did potential cost savings as they were not known at that time.

Similarly, M1 stated that the main driver for 2G network shutdown was spectrum refarming for 3G and 4G services. With declining 2G traffic, increasing use of mobile data, and fast uptake of 3G and 4G handsets and devices, M1 sought to refarm spectrum to ensure more efficient use of this scarce resource.

Ultimately reduction of costs may have been factored into the operators' decision in favour of the 2G switch-off. In interviews MNOs agreed that network operation is simplified from maintaining one less network. Once 2G equipment is no longer required, operation and maintenance costs are reduced and physical space (e.g. data centres and towers) is also freed.[93] Nevertheless in interviews no MNO explicitly identified cost savings as one of the main drivers.

In approving MNOs' requests to switch-off the 2G networks, IMDA took into consideration:[94]

- Rapid migration of consumers to 3G and 4G technologies – 2G subscriptions declined steadily from over 2 million in 2011 to about 250,000 subscribers in 2015 (3% of total mobile subscriptions) (Exhibit D.1);
- Widespread 3G and 4G coverage – in 2015 the three MNOs achieved 99% nationwide coverage for 3G services, and more than 98% at outdoor street level for 4G services;
- International trends – in 2015 mobile operators in Japan, Korea, Australia and the United States had either closed or announced plans to close their 2G networks;
- More efficient use of spectrum by reallocating 2G frequencies to provide more advanced 3G and 4G services;
- Obsolescence of some 2G network components and lack of vendor support; and
- The fact that many 2G subscribers were unaware of the technology being used for their mobile services.

Decisions on 3G network switch-off are being left to the MNOs. Spectrum allocated for 3G services (1,900 MHz and 1,900/2,100 MHz)[95] expires at the end of 2021. However, as 3G is used as a fallback for 4G handsets which do not support VoLTE, currently there are no plans for a shutdown of 3G networks.

92. IMDA (2001), Auction of Second Generation Mobile Communication Spectrum Rights – Information Memorandum, 27 July 2001. Page 4.
93. Ibid.
94. IMDA (2015), MNOs to close 2G networks from 1 April 2017, media release, 15 June 2015. Available at https://www.imda.gov.sg/news-and-events/Media-Room/archived/ida/Media-Releases/2015/mnos-to-close-2g-networks-from-1-april-2017.
95. 1900 MHz (TDD) spectrum was allocated together with 1900/2100 MHz (FDD) as part of a spectrum package in 2001 (the "2001 3G Auction') but has not been used and is currently the subject of an IMDA review. See www.imda.gov.sg/regulations-and-licensing/Regulations/consultations/Consultation-Papers/2019/Public-Consultation-on-Allocation-of-Spectrum-for-Enterprise-and-Public-Mobile-use.

D.3 Process

As part of the switch-off process IMDA requested that MNOs ensure a smooth transition for 2G subscribers. Both MNOs and IMDA engaged in media campaigns and roadshows to communicate and assist with the migration. MNOs contributed by announcing the changes on their websites[96,97] and shops, while IMDA undertook outreach to consumers via Members of Parliament and roadshows.

There were campaigns using TV, newspapers and posters in railway stations which carried the logos of all operators and IMDA. The decision to display IMDA and operators' logos helped to attract the attention of the public – if only MNO logos had been included, communications may have been perceived by consumers as advertising.

M1 engaged in a marketing campaign to inform consumers and offered a range of plans to encourage subscribers to sign up with new devices. Social media was also used to reach the public. StarHub launched an education campaign and contacted its own customers regularly.

International roaming partners were informed of the switch-off plans. Arrangements were made to accommodate inbound 2G roamers from international destinations with 3G handsets available to rent in airports. Stores selling 2G handsets at airports were informed about the switch-off. In addition to the marketing campaign other measures were taken to facilitate the migration, including:[98]

- 2G subscribers to continue with their existing mobile plans at no additional cost – 2G users were able to retain their numbers and subscription plans on the 3G/4G networks at no additional cost and with no re-contract;
- IMDA partnered with the MNOs to ensure that a range of handsets was available to meet various customer needs, from basic models costing below SGD50 to feature-rich smartphones. Handsets with features similar to 2G phones were also available; and
- Support for senior users – IMDA and MNOs partnered with community groups to reach out to seniors for providing support for the upcoming 2G switch-off. Also, IT learning hubs offered courses for seniors who wished to learn how to use smartphones.

The switch-off was coordinated amongst MNOs. The three operators agreed on a simultaneous switch-off, thereby avoiding any opportunities for any one operator to take advantage of the situation. The switch-off was completed in four days. It began in the east in areas of low demand and slowly moved toward the west of the market, gradually encompassing areas of higher demand.

96. Singtel (2015), Singapore to Cease 2G Services from April 2017, media release, 15 June 2015. Available at https://www.singtel.com/about-Us/news-releases/singapore-cease-2g-services-april-2017.
97. StarHub (2006), Cessation of 2G Services, Available at https://www.starhub.com/personal/support/services-and-plans/mobile-network/cessation-of-2g-services.html.
98. IMDA (2017), 2G Services to Cease on 1 April 2017, media release, 27 March 2017. Available at https://www.imda.gov.sg/news-and-events/Media-Room/Media-Releases/2017/2g-services-to-cease-on-1-april-2017.

D.4 Challenges

During the transition process MNOs found that handset stores were still selling 2G handsets at discounted prices. Even when MNOs were encouraging uptake by giving 3G handsets free of charge to 2G customers, people would sell them and continue using 2G. However, by 2017 no new 2G handsets were being sold. IMDA de-registered 2G-only mobile devices for sale for use in Singapore from 1 January 2017 – retailers and equipment suppliers were not allowed to sell 2G-only mobile devices from that date.[99]

The existence of M2M services over 2G was another of the challenges faced during the migration. M2M communications using 2G devices were common among enterprise customers managing fleets and sensor applications. For instance, a taxi company used 2G SIMS for M2M communications for its booking system. Some challenges arose in circumstances where MNOs were unaware of particular use cases – that is, there was no explicit contract with the MNO.

While the number of M2M connections relative to the total subscribers was small, there were some disputes regarding who would bear the migration cost. In many cases this became part of contractual negotiations and differences were settled as part of a contract renewal process.

D.5 Optimal conditions

2G switch-off in Singapore was initiated by the MNOs. The main driver for the MNOs' decision was optimising spectrum resources by focusing on high-value services – reuse freed 2G spectrum for 3G and 4G services. As spectrum rights in Singapore are not technology neutral, IMDA's permission was required to proceed with the switch-off. IMDA approved 2G switch-off and requested that operators ensure a smooth transition for 2G subscribers. The switch-off was coordinated among the three MNOs and was undertaken simultaneously in 2017, two years after IMDA made the public announcement.

By the time the switch-off was approved the number of 2G subscribers represented only 3% of the total, while the three MNOs had achieved 99% nationwide coverage for 3G services and more than 98% at outdoor street level for 4G services. Setting a long transition period, and collaboration and coordination between MNOs and IMDA contributed towards the success of the migration. For instance, IMDA partnered with MNOs in media campaigns to communicate and assist with the migration.

Interviewed operators indicated that some special arrangements were necessary with enterprise customers using M2M connections however, as the number of connections was relatively small compared to the 2G subscriber base, this was not a critical issue. The regulator confirmed that such issues were relatively minor, and that the transitional process had been smooth, with no complaints from consumers at the time of the switch-off.

99. IMDA (2016), Sale of 2G Mobile Devices for Local Use Will Not Be Allowed from 1 January 2017, media release, 7 December 2016. Available at https://www.imda.gov.sg/news-and-events/Media-Room/Media-Releases/2016/sale-of-2g-mobile-devices-for-local-use-will-not-be-allowed-from-1-january-2017.

Annex E: South Korea: 2G switch-off

The most active APAC markets in switching off 2G are markets with very dense populations with high levels of mobile data usage, a combination of factors which has put pressure on operators to free up spectrum for LTE[100]. As such, South Korea was one of the earliest markets to begin switching off 2G technology. KT, one of South Korea's operators, terminated 2G service completely on 19 March 2012. It initially announced its plans for 2G switch-off in January 2010.

On November 2019, SK Telecom filed a request to Ministry of Science, ICT and Future Planning (MSIP) to end its 2G services. The MSIP said it would process the request as soon as possible due to there being a need to focus on 5G services. If the IT Ministry approves SK Telecom's request, LG Uplus would be the only MNO that still provides 2G services. LG Uplus had previously said it would also end its 2G services before June 2021[101].

To date, there has been no clear announcement regarding 3G switch off from the South Korean operators.

E.1 Mobile market

Market evolution

In 2019, smartphone penetration in South Korea was at 95%, with the remaining 5% use a mobile phone which does not offer internet access. That makes it the only market with 100% mobile phone ownership[102].

GlobalData's South Korea Telecom Operators Market Intelligence Report also predicts that mobile broadband services will increase at the fastest CAGR of 3.1% during 2019-2024, led by fast growing machine-to-machine (M2M) connections, projected rise in adoption of 5G services and subsequent increase in mobile data average revenue per user (ARPU).

It is also predicted that 4G's total mobile subscriptions will decline from 79.2% in 2019 to 59.6% in 2024. With all the three major operators having launched their 5G services in April 2019 and expanding network coverage, 5G's share in total subscriptions is set to reach 40.1% by year-end 2024[103].

Market players

The three major market players in the South Korean mobile industry are SK Telecom, KT, and LG Uplus. Since the mid-90s, this group of companies has maintained a dominant share of the market in the mobile industry, and most sectors within the telecom industry more broadly[104].

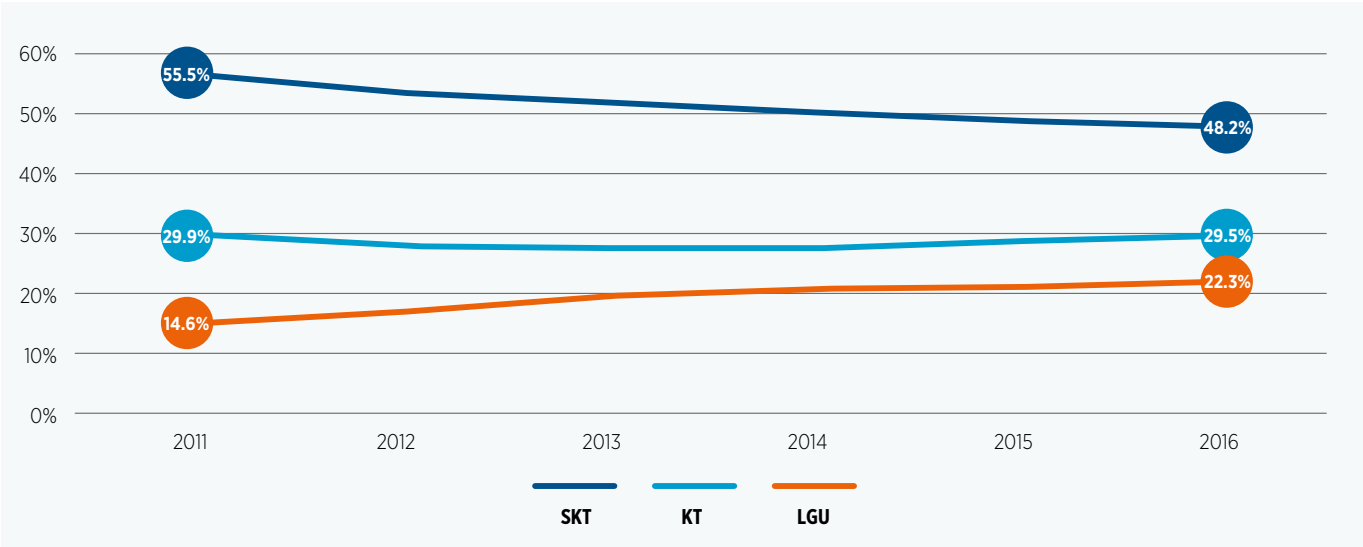
The cellular service revenue market in 2011 prior to KT's 2G switch off was led by SK Telecom, which had a 55.5% share. KT and LG Uplus trailed behind at 29.9% and 14.6% respectively (Exhibit E.1).[105]

100. "The Potential Impact of Switching Off 2G in the UK: A Report for the UK Spectrum Policy Forum by Real Wireless", October 2019.
101. https://www.zdnet.com/article/sk-telecom-to-end-2g-services/
102. https://deviceatlas.com/blog/mobile-landscape-south-korea
103. https://www.globaldata.com/decline-in-mobile-and-fixed-voice-revenue-to-drag-south-koreas-telecom-pay-tv-market-growth-during-2019-2024-says-globaldata/
104. https://telsoc.org/sites/default/files/tja/pdf/75-776-1-pb.pdf
105. https://plus.credit-suisse.com/rpc4/ravDocView?docid=_XCUS2AL-YxKG

EXHIBIT E.1

Source: Credit Suisse

CELLULAR SERVICE REVENUE MARKET SHARE (2011-16)[106]



In July 2019, there were 55.84 million 4G customers. SK Telecom accounted for 43.5% of 4G users, KT held a 27.5% share, and LGU+ had a 22.7% share of the 4G market, with MVNOs accounting for 6.3% of the 4G subscriber market[107].

In relation to 5G, South Korea became the first market in the world to commercially launch services on 3 April 2019. In early December 2019, it was reported that South Korea had reached 4 million subscribers and it was expected that the market would have 5 million subscribers by the end of 2019.[108]

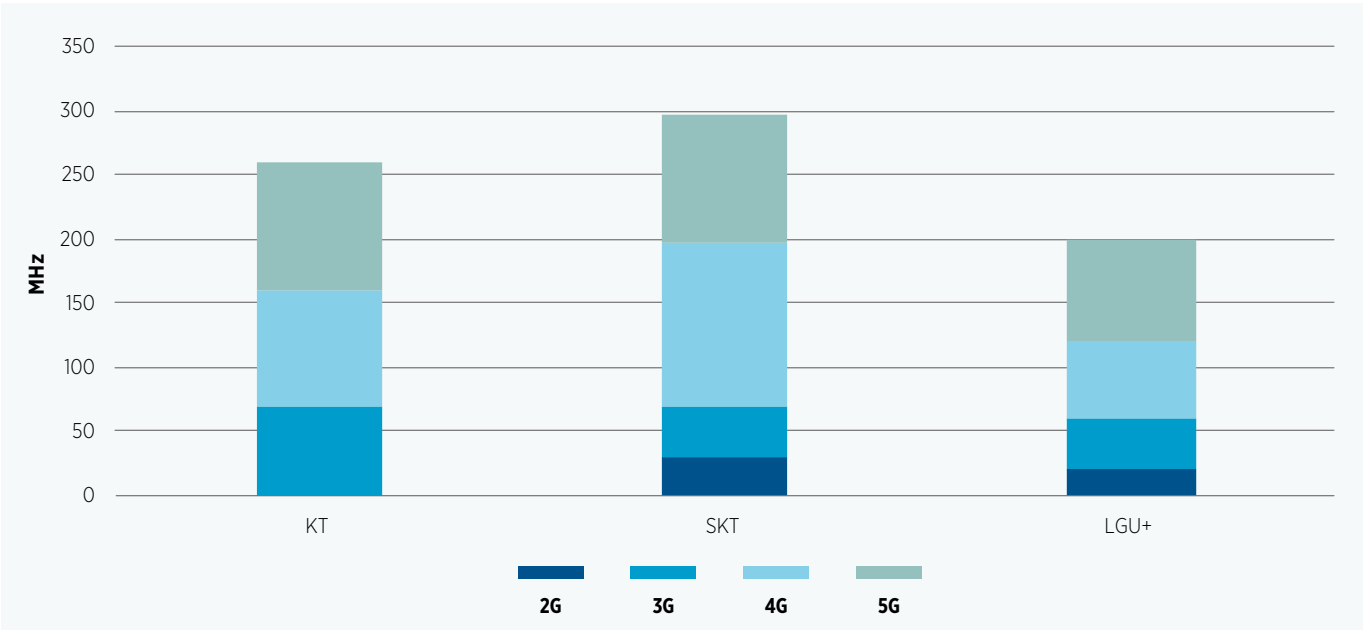
Allocation of network frequencies

Exhibit E.2 shows the allocation of network frequencies in South Korea.

EXHIBIT E.2

Source: Credit Suisse

IMT BAND ALLOCATION IN KOREA NOT INCLUDING MMWAVE ALLOCATIONS[109]



106. Credit Suisse 2017.
107. https://www.lightreading.com/asia-pacific/south-korea-closed-july-with-nearly-2m-5g-subs/d/d-id/753810
108. https://www.telecompaper.com/news/south-korea-passes-4-million-5g-subscribers-milestone-to-hit-5-mln-5g-users-by-end-2019--1318417
109. https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/SiteAssets/Pages/ConformityandInteroperability2018/Session%202-5.pdf

Additionally, the Exhibit above shows the band plan following the June 2018 spectrum auction. SK Telecom and KT each won 100 MHz of the 3.5 GHz spectrum, while LG Uplus secured 80 MHz. All three mobile operators secured 800 MHz of the 28 GHz spectrum. They can use the 3.5 GHz spectrum for the next 10 years and 28 GHz spectrum for five years[110].

South Korea is also to double the amount of 5G spectrum it makes available for its next generation mobile networks by the end of 2026. It plans to make an additional 2,680 MHz of spectrum available by the end of the year 2026, putting the total amount of 5G spectrum in the South Korean market at over 5,320 MHz[111].

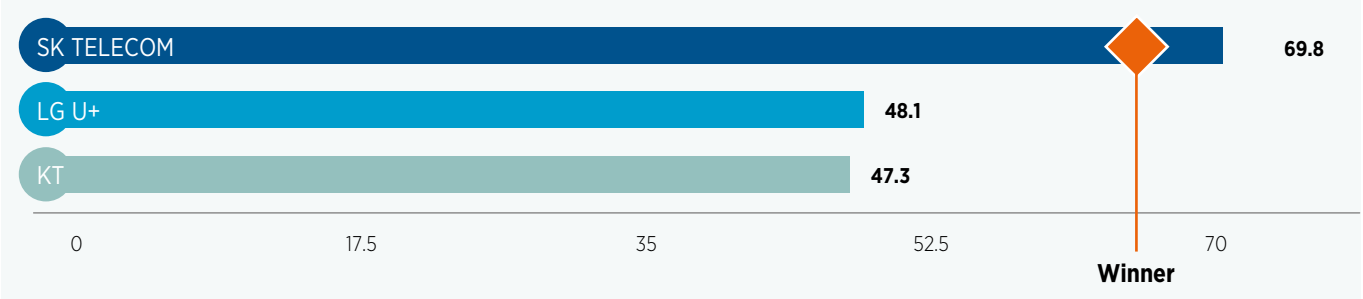
Mobile experience

Prior to KT's 2G switch off in 2012, South Korea already had the fastest average Internet connection speed globally[112]. According to Open Signal's Mobile Network Experience Report published in December 2019, the mobile experience in South Korea today remains among the best in the world. As shown below in Exhibit E.3, South Korea has the fastest network connections in the world, with SK Telecom users experiencing average speeds of 69.8Mbps. Users on LG Uplus and KT also enjoy extremely fast speeds in comparison with other markets[113]. This speed is set to further improve dramatically with 5G coverage estimated from industry sources at 85 percent population coverage[114] – and reportedly 5G networks are already carrying over 20 percent of all wireless traffic.[115]

EXHIBIT E.3

Source: Opensignal December 2019

DOWNLOAD SPEED EXPERIENCE (IN MBPS)[116]



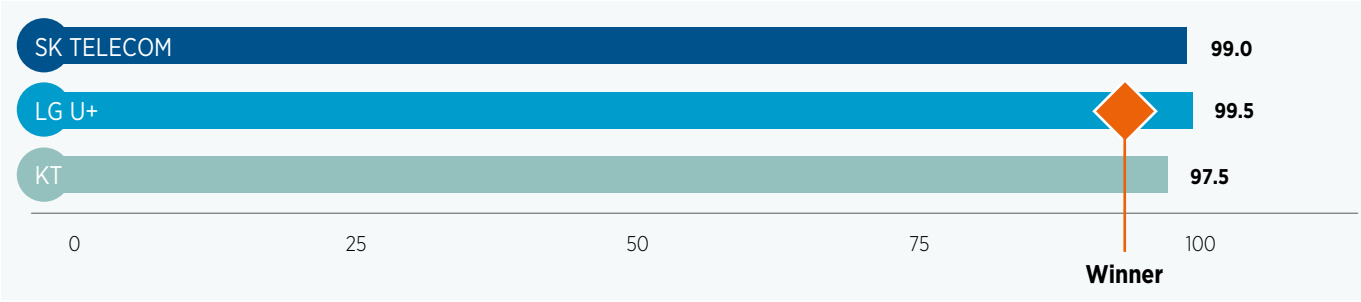
Additionally, all three South Korean operators were able to deliver a 4G signal to users more than 97% of the time, putting them among the global elite in 4G reach (Exhibit E.4). LG Uplus achieved a near-perfect score in 4G availability, meaning that there was practically no instance where Open Signal users were unable find a 4G connection during the data collection period[117].

110. https://www.zdnet.com/article/south-korea-completes-5g-spectrum-auction/
111. https://www.totaltele.com/504372/S-Korea-to-double-5G-spectrum-allocation-by-2026
112. https://royal.pingdom.com/south-korea-is-still-number-one-has-fastest-internet-speed-worldwide/
113. www.opensignal.com/reports/2019/12/southkorea/mobile-network-experience
114. https://www.totaltele.com/504149/KT-sets-sights-on-85-coverage-in-second-phase-of-worlds-first-commercial-5G-network
115. http://www.strategyanalytics.com/access-services/service-providers/service-providers-strategies/reports/report-detail/south-korea's-5g-market-carries-over-20-of-traffic-in-december-2019
116. Opensignal 2019.
117. www.opensignal.com/reports/2019/06/southkorea/mobile-network-experience; and www.opensignal.com/reports/2019/12/southkorea/mobile-network-experience https://www.zdnet.com/article/sk-telecom-to-end-2g-services/

EXHIBIT E.4

Source: Opensignal

4G AVAILABILITY (% OF TIME)



E.2 Key drivers

SK Telecom wishes to phase out its 2G services for several reasons.

First, the spectrum used for 2G could be allocated elsewhere for better use. With only 2% of its total subscribers still using 2G[118], the spectrum currently being utilised for 2G could instead be allocated to more advanced technologies such as 4G LTE or 5G. 5G services are much more spectrum efficient than 2G due to its lower spectrum bands. The increased efficiency offered by 5G can then be translated into significant cost savings and increased coverage for subscribers.

Second, the desire to switch off 2G was also based on the obsoleteness of 2G networks where key components can be no longer be procured. In addition, since handset manufacturers such as Samsung and LG have not provided 2G handsets since 2014, any technical problems arising from out-of-date 2G handsets cannot be easily rectified.

In the case of LG Uplus, that the operator has yet to announce plans to switch off 2G is likely due to its relatively modern 2G network. Further, a 2G phase out has been delayed as the MNO lacks a 3G network, and as such would first need to back up its 4G services. In the future, LG Uplus may consider 2G switch off for cost saving issues, as well as increased coverage and spectrum efficiency.

118. https://www.zdnet.com/article/sk-telecom-to-end-2g-services/

E.3 Optimal conditions

Government approval

According to Article 19 of Telecommunications Business Act (English translation), MNOs must acquire permission from the MSIP for service termination and should notify subscribers at least 60 days prior to the intended termination date. Before March 2013 when amendments were made to the law, MNOs were required to obtain approval from the from the Korea Communications Commission (KCC), instead of the MSIP. It is understood that Presidential Decree of the Telecommunications Business Act lists the documents that MNOs must submit to obtain the MSIP's permission at least 60 days prior to the intended date for termination.

As detailed in the article "Terminating 2G Service in Korea: Policy Issues and Suggestions"[119]:

- The official process begins with an MNO's submission of a termination plan to the MSIP (the KCC in the past). After reviewing the plan, the MSIP may accept the plan or ask for revision. If the MSIP accepts the plan, an MNO can take steps to terminate the service, while soliciting remaining subscribers to transfer to its advanced services or other MNOs' 2G service or advanced services; and
- After at least two months have passed since the plan is accepted, the MNO can request permission for service termination from the MSIP. When permission is granted, the MNO can finally terminate the service following the conditions specified in an MNO's existing subscription contracts.

Small 2G user base

It is crucial for MNOs to ensure that they have a 2G user base that is small enough to gain government approval. When KT acquired approval from the government in February 2012, a month before their 2G switch-off their 2G subscribers had decreased to 150,000, around 1% of their total mobile subscribers[120].

In October 2019, at the time of its 2G switch off application, the number of SK Telecoms' 2G subscribers was at 570,000 subscribers, around 2% of its total mobile subscribers. SK Telecom would need to cut down 2G to less than 270,000, or about 1% of total subscribers, in order to end 2G with a comparatively low user base[121].

Sufficient user protection

In order to assist in the transition of its customers from 2G, SK Telecom is currently offering discounted data plans to its 2G subscribers to migrate to 3G, LTE, or 5G[122]. The MNO also plans to support terminal purchase costs and charges to help existing 2G users switch their networks and use existing numbers until June 2021[123].

However, the government requires additional measures for protecting end-users, including corporate customers and MVNO subscribers hosted by SK Telecom. As such, the MSIP's decision regarding SK Telecom's 2G switch off application has been delayed as the operator has yet to submit all the data requested by the government on its user protection measures[124]. This delay highlights the importance of operators providing appropriate security to its remaining 2G subscribers when 2G is phased out.

119. Kwon, N and Kwon, Y, "Terminating 2G Service in Korea: Policy Issues and Suggestions", International Telecommunications Policy Review, Vol.21 No.1 March 2014, pp.1-26.
120. http://www.digitaltoday.co.kr/news/articleView.html?idxno=220172
121. Ibid.
122. https://www.zdnet.com/article/sk-telecom-to-end-2g-services/
123. https://www.sedaily.com/NewsView/1VQPGPDYJV
124. http://news.heraldcorp.com/view.php?ud=20200109000202

E.4 Case study: KT's early 2G switch-off

In the process of switching off its 2G network from 2011 to 2012, KT faced delays enforced by the regulator, Korea Communications Commission (KCC), and a class action lawsuit from 900 subscribers[125]. The process lingered on for about nine months from the date that KT initially planned to shut down the network.[126] These delays reflect how a regulator-coordinated process of switching off generally involves increased oversight of MNOs' plans for service termination, as well as the imposition of certain conditions that must be met before switch off can occur.

Switching off while KT still had large 2G user base

KT was initially denied permission by KCC to switch off 2G because there were too many remaining 2G subscribers. It still had 5% of its total base (about 810,000 users at the time) on 2G.

Short notice period

As detailed in the article *"Terminating 2G Service in Korea: Policy Issues and Suggestions[127]"* the second reason for denying permission was that the period of notice to subscribers was too short. KT only three months' notice to subscribers that it planned to switch off 2G. The KCC pointed out that although it satisfied the condition specified in the Act (minimum of 60 days), three months was too short a period for remaining subscribers to transfer to other services." This brief transition period did not allow enough time to educate and inform those customers about transition options.

By contrast, Japanese MNOs set a much longer lead time for 2G service termination than KT did. Softbank announced its intention to discontinue 2G services around 21 months earlier than the scheduled termination date. Similarly, NTT Docomo also publicised its 2G service termination policy more than three years before the scheduled termination date[128].

The regulator's conditions for approving switch off

KT's proposed termination of its 2G network was approved by the KCC only after various criteria were met. These included the following:

- 2G customers make up less than 1% of total mobile subscribers;
- Availability of alternative services for 2G subscribers;
- Publicity campaigns;
- Consumer protection; and
- Availability of compensation packages[129].

The operator also offered various incentives for users to move to 3G including exemption from 3G subscription fees for the first three months, followed by discounted rates for two years; free devices; and a payment of KRW33,000 (USD27) for a returned 2G device. Other benefits included loyalty points and air miles.

The case study has been widely cited by other MNOs as an important reminder to drive the 2G base down to a small percentage of the total subscriber base before setting a firm deadline for sunset[130].

Lessons learned

A recent report by Real Wireless has noted that operators which have reported disruption to their own businesses, and to their customers, have often been those, like KT, which tried to turn off 2G while they still had a substantial 2G base of users, and without allowing sufficient time[131]. As such, MNOs which shut down 2G in the 2020s are likely to face fewer challenges than those who moved very early. Not only are there emerging alternatives to 2G, such as NB-IoT, to support service migration, but MNOs can learn from the problems that early movers such as KT encountered.

125. Ibid; "The Potential Impact of Switching Off 2G in the UK: A Report for the UK Spectrum Policy Forum by Real Wireless", October 2019.
126. Kwon, N and Kwon, Y, "Terminating 2G Service in Korea: Policy Issues and Suggestions", International Telecommunications Policy Review, Vol.21 No.1 March 2014, pp.1-26.
127. Ibid
128. "The Potential Impact of Switching Off 2G in the UK: A Report for the UK Spectrum Policy Forum by Real Wireless", October 2019; Kwon, N and Kwon, Y, "Terminating 2G Service in Korea: Policy Issues and Suggestions", International Telecommunications Policy Review, Vol.21 No.1 March 2014, pp.1-26.
129. Kwon, N and Kwon, Y, "Terminating 2G Service in Korea: Policy Issues and Suggestions", International Telecommunications Policy Review, Vol.21 No.1 March 2014, pp.1-26.
130. "The Potential Impact of Switching Off 2G in the UK: A Report for the UK Spectrum Policy Forum by Real Wireless", October 2019.
131. Ibid.

Annex F: Macao, SAR

In Macao, SAR in early 2012, the Telecommunications Regulation Bureau of Macao, SAR (DSRT) announced that the 2G closure was to occur on July 2012. However, switch off was postponed twice due to network destabilisation and a series of outages , before 2G was finally closed in June 2015. Note that while MNOs had ceased offering GSM-based 2G services for domestic users at this time, they still maintained services for roaming PRC visitors.

The 2G switch off in Macao, SAR for domestic users was announced 3.5 years before closure. During this transition period, the number of 2G users decreased for all MNOs. By the time 2G was closed, SmarTone was the only operator to have any 2G users remaining (Exhibit F.1).

EXHIBIT F.1

Source: industry and vendor reports

MACAO, SAR'S 2G/3G SWITCH OFF DATES

Operator	Announcement Date	2G users at announcement (%)	Close Date	2G users at close (%)	Transition period
SmarTone Macau	28 March 2012	22.9%	4 June 2015	0.02%	3.5 years
CTM		10%		0%	
Hutchison Telecom		1.07%		0%	

In April 2019, the Post and Telecommunications Bureau (CTT)[133] approved a plan for Macao, SAR's three MNOs to fully switch off their 2G networks. Under this plan, operators were free to switch off their legacy GSM systems from 1 August 2019[134]. Macao, SAR is following the international development with over 90% of telecom services users on the 4G network, and there have been no new subscribers to the 2G network in recent years[135].

The full 2G switch off will now allow the Macao, SAR government to make use of the frequency bands that would no longer be occupied by 2G, while operators will be able to concentrate resources on improving and developing other network technologies and services[136].

With the upcoming 5G network service, it is also expected that the 3G network will end its service in the near future[137].

Mobile market

Macao, SAR boasts a sophisticated and independently regulated communications market. Competition is intense in Macau's mobile market, with four MNOs and a MVNO offering services. The MNOs are SmarTone Macau, CTM, Hutchison Telecom, and China Telecom. All four operators offer 4G LTE services. Gradual liberalisation has now fully opened the telecoms market with the full impact slowly becoming evident.

Mobile subscriber and mobile penetration rates are high, exceeding 300%. This high figure is due to the in excess of 20 million visitors that visit Macao, SAR annually as well as the usage of multiple sim cards by mobile subscribers. Mobile broadband has also presented mobile operators with an additional revenue growth opportunity, driving investment in 4G LTE and 5G networks.

Following the introduction of the global 5G standard, CTM has begun testing 5G wireless technology. If the 5G license and spectrum arrangements progress well, 5G in Macao, SAR will synchronize with the neighbouring regions which plan to launch 5G services for commercial use in 2020[138].

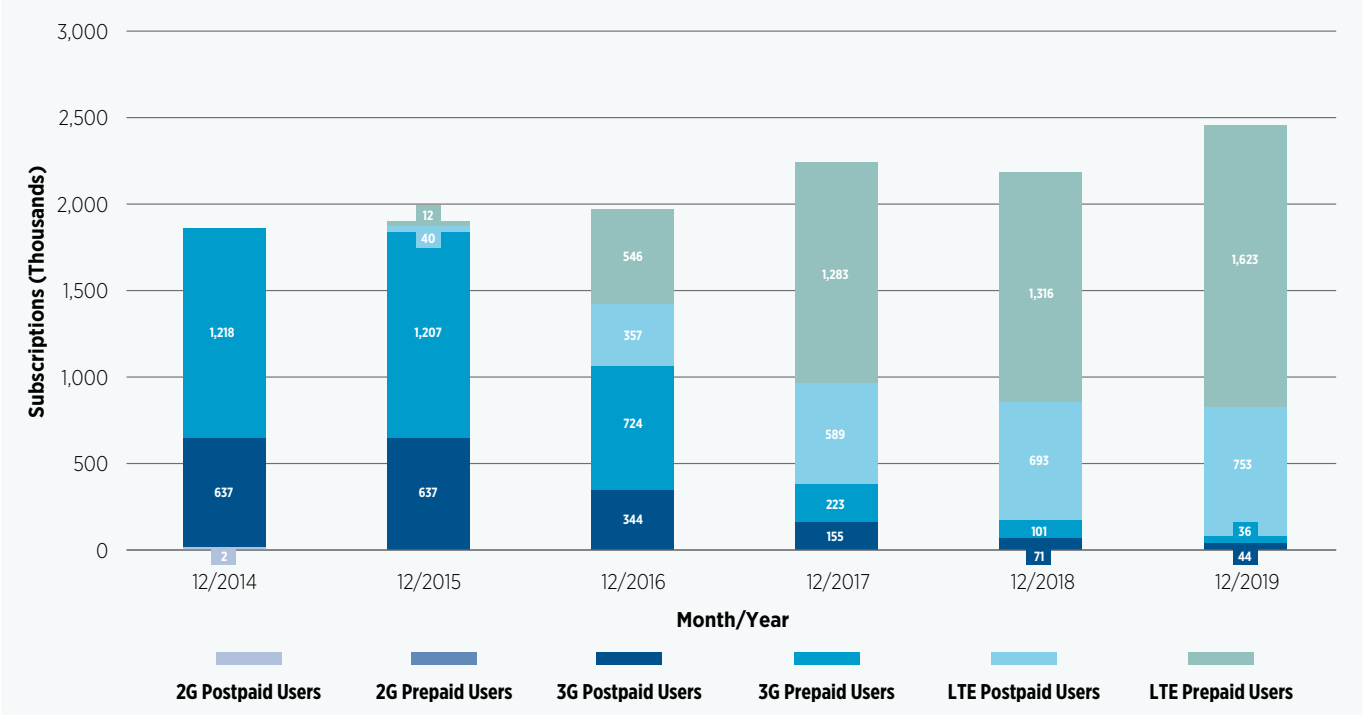
133. The government merged the Telecommunications Regulation Bureau (DSRT) and Macau Post Office into the Macau Post and Telecommunications Bureau (CTT) on 1 January 2017: See https://macaunews.mo/auditor-slams-macau-wifi-go-poor-connection/
134. https://alertify.eu/macau-to-shut-down-2g-networks-for-roaming-users/
135. https://macaunews.mo/govt-to-allow-telecoms-to-end-2g-service/
136. Ibid; https://alertify.eu/macau-to-shut-down-2g-networks-for-roaming-users/
137. https://macaunews.mo/2g-is-history-ctm/
138. https://www.budde.com.au/Research/Macau-Telecoms-Mobile-and-Broadband-Statistics-and-Analyses

Exhibit G.2 below shows how the number of LTE users have dramatically increased since 2014, as well as how subscribers of 2G and 3G have rapidly dropped. In November 2019, there were 1,623,000 LTE prepaid users in Macao, SAR, while the number of 2G users had dropped to zero.

EXHIBIT F.2

Source: CTT 2019

MOBILE SUBSCRIBERS AS OF DECEMBER 2019[139]



The key conclusions from this short case study are that (i) network capacity issues need to be addressed ahead of any switch-off and (ii) it may be sensible for commercial reasons for MNOs in small markets to continue to operate legacy 2G or 3G services if the market has a large number of roamers due to the customer base in their neighbours.

139. CTT 2019. See: https://telecommunications.ctt.gov.mo/web/en/generalinfo/statistics/mainchart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