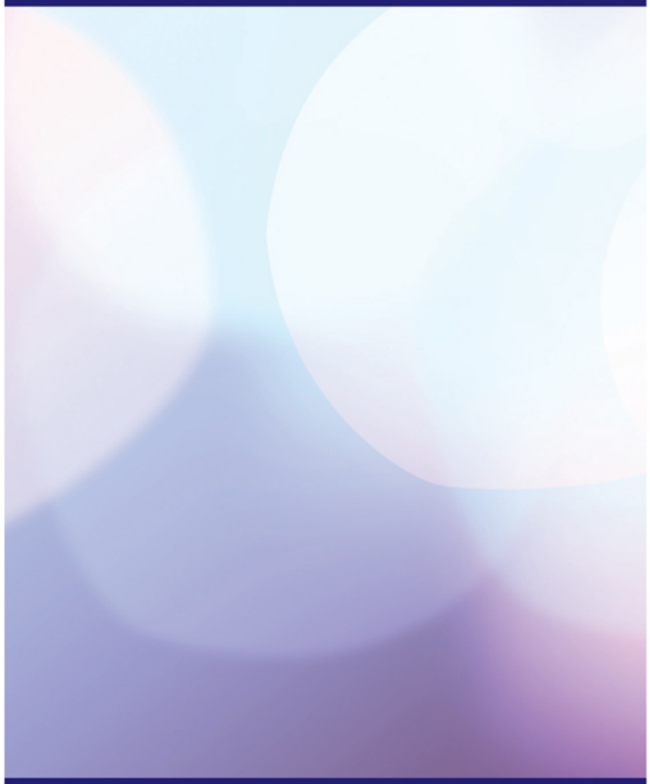
analysys mason



www.analysysmason.com

Report for CEDB

Study on the implementation of spectrum trading in Hong Kong

31 May 2018

David Abecassis, Janette Stewart, Jon Coates, Christian Koboldt, Mark Colville

Ref: 2010006-161

Contents

Analysys Mason Limited
Rm. 1046, 10/F Wharf T&T Centre
7 Canton Road, Tsim Sha Tsui
Kowloon
Hong Kong
Tel: +852 3669 7090
hongkong@analysysmason.com
www.analysysmason.com
Registered in Hong Kong with Business Certificate No. 65574359-000-12-15-9

Executive summary

CEDB commissioned a consultancy study undertaken by Analysys Mason Limited (Analysys Mason) and DotEcon Limited (DotEcon) on issues relating to spectrum trading for public mobile telecoms services.

The objectives of the consultancy were to:

- study the latest overseas experience in respect of spectrum trading;
- assess the demand for and supply of spectrum for trading in Hong Kong based on current market practices and the competitive landscape;
- evaluate and analyse the benefits and costs of introducing a spectrum trading regime in Hong Kong; and
- advise how a spectrum trading regime should be introduced if such a regime is pursued in Hong Kong, while also proposing alternative methods to enhance spectrum efficiency in Hong Kong if such a regime is not pursued in Hong Kong.

Latest overseas experience in respect of spectrum trading

Based on comprehensive research into the extent of implementation of spectrum trading in different markets worldwide, we have identified three major scenarios with respect to the implementation (or otherwise) of spectrum trading, namely:

- **Category 1**: A clear spectrum trading regime is implemented through specific legislation (e.g. the UK, USA, Canada, Australia and New Zealand)

- **Category 2**: Spectrum trading is allowed, albeit not through a full-fledged trading regime (e.g. Singapore, Luxembourg and Switzerland)

- **Category 3**: No spectrum trading is allowed (e.g. Japan and Mainland China)

Hong Kong falls into Category 3.

In summary, we have found that not all markets have introduced spectrum trading.

In most case study markets where spectrum trading has been introduced, the use of mobile spectrum trading has been relatively low.

In case study markets with low spectrum trading volumes, trading has typically been used to rejuvenate underutilised spectrum (i.e. in instances where assigned spectrum was not fully used by the licence holder), and to respond to changing technology and service demands.

A higher volume of mobile spectrum trading activity exceptionally occurs only in Canada and the USA, and this can be largely attributed to the two countries' regional spectrum licensing regimes, which is not applicable to Hong Kong.

Our analysis suggests benefits of spectrum trading cited internationally include the following:

- aggregation of regional spectrum holdings
- rejuvenation of under-utilised spectrum
- lowering barriers to expansion
- flexibility to allow spectrum use to evolve with changing market demands
- flexibility to change the use of spectrum in regimes with long or perpetual licences
- reduction of administrative burden on the regulator.

On the other hand, the introduction of spectrum trading may give rise to potential costs/risks, such as:

- spectrum hoarding, including speculative hoarding
- windfall profits and other private profits gained by trading parties
- over-concentration of spectrum
- loss of harmonisation
- increased risk of interference
- distortion of auction dynamics.

The potential costs/risks to spectrum trading implementation need to be properly managed and addressed, through a range of safeguards, and balanced against the costs, in the overall consideration as to whether a spectrum trading regime should be implemented.

Supply of and demand for spectrum for trading in Hong Kong

In considering whether there is a need to introduce spectrum trading with a view to promoting efficient use of spectrum, we have examined the current spectrum management regime in Hong Kong to gain insights on its effectiveness in ensuring optimal spectrum use and to ascertain whether there are alternative tools which could also potentially be adopted or enhanced to achieve similar benefits to that of the introduction of spectrum trading. We have also assessed information on the latest market conditions derived from industry interviews.

Our review indicates that Hong Kong's current spectrum management framework for public mobile telecoms services is reasonably effective in promoting the efficient use of spectrum. Spectrum is assigned for a fixed term and not assigned perpetually, usually through market-based mechanism as in auction in respect of newly available spectrum. Spectrum is generally re-assigned upon expiry of term by adopting a re-assignment arrangement that embodies in it an auction element.

This creates opportunities, from time to time, for those players, including incumbent mobile network operators (MNOs) and new interested parties, who wish to acquire spectrum, to bid for the spectrum. This also creates opportunities, from time to time, for incumbent MNOs to review their overall spectrum holdings in deciding whether to take part in the competitive bidding of spectrum that takes place periodically, based on their commercial considerations. Should they so decide, they can participate in auctions held by the Office of the Communications Authority (OFCA), the executive arm of the Communications Authority (CA), the independent statutory regulator.

The current regulatory regime also supports operators in various ways to achieve efficient use of spectrum: the technology-neutral principle in spectrum management, the spectrum swap mechanism and mobile network sharing all assist operators to flexibly and timely adapt to changing technological and market conditions.

One of the major benefits of spectrum trading is that, if an MNO does not have enough capacity to meet its short-term need, it may acquire the spectrum from the market through commercial deals with other MNOs.

In the case of Hong Kong, MNOs are already allowed to implement certain types of mobile network sharing, such as antenna sharing, site sharing, radio access network sharing and capacity leasing through commercial arrangement with other MNOs. These sharing arrangements serve as viable alternatives to resolve MNOs' short-term need for additional capacity. For longer-term need for spectrum capacity, as mentioned above, MNOs could bid for additional spectrum by taking part in the auctions to be conducted by the CA regularly when new spectrum is available, or when assigned spectrum is returned to the CA upon expiry of the spectrum assignment periods for re-assignment.

In the industry interviews we conducted, we found mobile spectrum to be in high demand with operators, bearing in mind the Hong Kong market's incessant demand for mobile data services and the need for operators to prepare for the launch of fifth generation (5G) mobile services. Demand for additional spectrum (especially in the sub-3GHz spectrum bands) will likely be sustained in the short term, and it is expected that some of industry's demand for spectrum may translate to potential demand for spectrum trading.

Practically speaking, spectrum utilisation in Hong Kong is currently generally high and MNO market shares remain relatively stable. There is no indication of significant changes in market share that will result in an operator having significantly less usage requirements. Particularly for spectrum in the sub-3GHz spectrum bands, given its availability in the primary market would remain constrained in the short term, it is unlikely that spectrum holders would be willing to sell their spectrum resources in the secondary market. Therefore, even if spectrum trading were permitted, the potential supply of spectrum in the secondary market remains in question.

Against the above, trading activity is anticipated to be low in the short term, and so would the benefits so derived.

Overall demand for spectrum trading may also be affected by the on-going spectrum auctions conducted to release new spectrum for mobile services. The latter is being proactively addressed by the CA, particularly in frequency bands above 3GHz, in preparation for commercial launch of 5G from 2019/2020 onwards. MNOs or other interested parties could potentially wait for the availability of new spectrum, and acquire it for a full 15 years' term, rather than negotiating with the incumbents to trade for the assigned spectrum (which involves additional transaction costs) for the remaining duration of the assignment period.

In addition, from our interviews with the operators, most of them did not express clear intentions to participate in the secondary market for spectrum. While one operator heavily supported the

introduction of a spectrum trading regime, others were less keen, stating fears of increased risks due to anti-competitive activities.

Benefits and costs of introducing a spectrum trading regime in Hong Kong

In terms of overall benefits, certain benefits arising from spectrum trading will not be applicable to Hong Kong as Hong Kong does not have regional licensing or perpetual licensing terms.

Regarding costs and risks of spectrum trading, feedback from stakeholders suggest that costs related to spectrum hoarding and over-concentration of spectrum should be taken seriously. In addition, there may not be a satisfactory solution to resolve the problem of windfall gains and other private gains.

In the short term (five years), the introduction of spectrum trading in Hong Kong appears to be a balancing act among (a) the introduction of more flexibility to the overall spectrum assignment regime in terms of permitting asymmetric trades (including partial trades of spectrum holdings) and increased time flexibility in determining when to acquire or relinquish spectrum and (b) costs and potential risks associated with spectrum trading, and (c) safeguards and further regulatory controls required to forestall/alleviate such costs and risk and the related implementation costs.

To elaborate, at present, there is no critical bottleneck in the Hong Kong market that requires spectrum trading as the only resolution. This is because the current spectrum management framework for public mobile telecoms services already appears to be reasonably effective in promoting the efficient use of spectrum under existing regulatory mechanisms (e.g. assignment/re-assignment opportunity at regular intervals, capacity leasing mechanism). We also note that as spectrum for public mobile telecoms services is relatively well utilised in Hong Kong, the supply of mobile spectrum for trading and thus level of trading activity is anticipated to be low in the short term, as would be the benefits so derived.

The implementation timeline required to set up the spectrum trading regime is an important consideration in the short term. Various jurisdictions have dedicated a significant amount of time to set up spectrum trading regimes. Given the time it takes to set up and the availability of existing regulatory mechanisms (including re-assignment opportunities at forthcoming auctions), the window of opportunity for a spectrum trading regime to have an impact on the Hong Kong market may be limited in the short term.

Hence, considering the above, the limited benefits expected in the short term in Hong Kong may not justify the associated costs for introducing and implementing such a regime. In this regard, there is limited justification to support the setting up of a spectrum trading regime in the short term, having considered the time needed to implement, and the risks, and costs.

In the medium term (five to ten years), 5G is expected to be the main driver for mobile spectrum usage and development. However, 5G standards are still evolving and 5G use cases are not yet entirely clear. The different possible use cases for 5G (e.g. enhanced mobile broadband, IoT) have differing implications on how mobile networks might need to evolve. Additional spectrum management considerations are likely to occur in relation to spectrum access for 5G use cases other

than mobile broadband. Whilst the technological advances in mobile networks envisaged for 5G are such that multiple logical networks can be provisioned from one physical network (i.e. through slicing), it is possible that new spectrum demands will emerge (e.g. in relation to possible demand for private 5G networks for industrial IoT use cases). There might also be demand for private in-building 5G networks. There might be a need to consider more flexible approaches to spectrum assignment.

There is a possibility that the additional flexibility brought about by spectrum trading would be useful to cope with 5G development and roll-out. That said, we note that current mechanisms already provide some flexibility to allow use of existing mobile spectrum to evolve with the needs of 5G (e.g. re-farming of technology-neutral spectrum holdings for future 5G technologies). The expiry of existing spectrum assignments within the next ten years also provides opportunities for the CA to reorganise the band plans if necessary before the new term of assignment. There has thus yet to be a clear case for implementing spectrum trading in Hong Kong in the medium term.

In addition, it is likely that the supply of 5G spectrum in the frequency range 24.25–86GHz would be large. Although demand is still uncertain at this stage, should it be the view of the CA that there are no competing demands for 5G spectrum in the primary assignment, pursuant to the Radio Spectrum Policy Framework, this spectrum may be assigned administratively instead of through auction. In such a scenario, spectrum trading is not relevant.

Proposed approach to spectrum trading implementation if pursued, and alternative methods to enhance the spectrum efficiency in Hong Kong if not pursued

If a trading regime were to be pursued in Hong Kong, it is important to build on the existing regulations and practices adopted by the Government to minimise implementation complications resulting from inconsistencies between a new trading regime and the existing spectrum management framework.[1]

This would suggest that each prospective trade shall be reviewed on a case-by-case basis, using a two-tier approval process, to allow each trade to be considered based on its relevant technical merits. This regulatory approval process is the key safeguard to prevent trades that will reduce overall technical and market efficiency. Pre-existing safeguards i.e. network and service roll-out requirements, and clear definition of spectrum lot sizes and technical conditions, also serve to safeguard against other costs related to spectrum hoarding, loss of harmonisation and the risk of interference.

We note that safeguards may not be effective in eliminating all potential costs/risks. This is particularly evident for the risk of windfall gains and other private profits to be gained by trading parties. Regulatory review of trades may remove some of the risk associated with excessive profits being gained by

[1] Depending on the types of trading to be implemented, some changes to existing regulations and/or to the spectrum management framework might be required (e.g. if liberalisation is allowed, it may be necessary to define technical usage conditions for licences to be suitable for trading).

operators. However, this might not comprehensively resolve the issue as approved trades could still be conceived as 'unfairly benefiting' trading parties without stimulating productivity or competition.

Rather than spectrum trading, there are other mechanisms that can be used to effectively create a more flexible environment for spectrum assignment/re-assignment and to enhance spectrum efficiency in the Hong Kong market.

We have drawn on existing regulatory frameworks, and propose the following three enhancements to current spectrum management mechanisms that could help enhance spectrum use in Hong Kong, without implementing spectrum trading, namely:

- Enhanced mobile network sharing arrangement
  - combination of existing RAN-sharing and capacity leasing mechanisms
- Periodically adjusted SUF for administratively assigned spectrum
- Enhanced spectrum swap
  - inter-band and/or asymmetric bandwidth spectrum swaps.

Conclusion

In conclusion, spectrum trading may be a useful tool to enhance spectrum flexibility and efficiency, especially in certain market environments, e.g. those featuring regional licensing or perpetual licensing system. There are however potential costs to spectrum trading implementation that need to be carefully mitigated through a range of safeguards; and there are risks that might not be adequately addressed despite safeguards.

In the case of Hong Kong, it already has a spectrum management system which is reasonably effective in promoting efficient use of spectrum. Insofar as further enhancing the efficient use of spectrum and improving market flexibility are concerned, there are other spectrum management tools that can be used. The other tools could also potentially be enhanced to achieve similar benefits to that of the introduction of spectrum trading, without incurring the associated costs and risks. This suggests there is limited justification for introducing spectrum trading in Hong Kong in the short and medium term.

In the longer term, the potential 5G spectrum-related challenges are likely to be complex and interlinked. Hong Kong should monitor the technology and market developments as well as the allocation of mobile spectrum for 5G in the coming years and the implications on the spectrum assignment regime for mobile services both in primary and potentially in secondary assignments, with a view to keeping it up to date in the 5G era.

1 Introduction

This is the report for a consultancy study being undertaken by Analysys Mason Limited (Analysys Mason) and DotEcon Limited (DotEcon) on issues relating to the spectrum trading for public mobile telecoms services.

The objectives of the consultancy are to:

- study the latest overseas experience in respect of spectrum trading
- project the demand for and supply of spectrum for trading in Hong Kong based on current market practices and landscape
- evaluate and analyse the costs and benefits of introducing a spectrum trading regime in Hong Kong
- advise how a spectrum trading regime should be introduced if such a regime is pursued in Hong Kong, while also proposing alternative methods to enhance the spectrum efficiency in Hong Kong if such a regime is not pursued in Hong Kong.

1.1 Background to the study

The market for wireless technologies is rapidly evolving, with consequential growth in demand for access to radio spectrum. Wireless technology underpins the operation of many essential services in today's networked economy. This includes the use of smartphones and other handheld devices to provide mobile connectivity; wireless data connectivity using Wi-Fi technologies; production and distribution of live TV and radio programmes; satellite communications; and wireless communications used in transport, aviation and a wide range of public services, including public safety and defence.

One of the Government of Hong Kong's goals is to strengthen the country's strategic position as a world city and as the world's gateway to Mainland China. Ensuring the widest possible availability of high-speed wireless and mobile connectivity is a key step in achieving this goal. Fourth generation (4G)[2] services are already widely available in Hong Kong. Operators are investing to achieve higher throughputs and speeds by acquiring additional spectrum and configuring spectrum to use the latest LTE-A features (such as carrier aggregation). Fifth generation (5G) mobile technology is likely to further enhance the availability of high-speed mobile broadband services. 5G will also position the mobile networks to meet the various speed, reliability, latency and massive connectivity requirements of mission-critical communications, Internet of Things (IoT) and other innovative applications and services, which is poised to transform the international communications landscape. The availability of radio spectrum, a sound spectrum management framework and the flexibility to allow operators to configure spectrum to achieve their business goals can help to achieve these objectives.

[2] Primarily LTE and LTE-A services.

The Communications Authority (CA), the independent statutory regulator, supported by the Office of the Communications Authority (OFCA), the CA's executive agency, manages and administers radio spectrum in Hong Kong in accordance with the Telecommunications Ordinance (TO) (Cap. 106). Policies relating to spectrum management are overseen by the Hong Kong Government via the Commerce and Economic Development Bureau (CEDB).

According to the Radio Spectrum Policy Framework promulgated by the government in 2007, the CA adopted a market-based approach to spectrum management (including the use of auctions). The CA adopts this approach when it considers that there are likely to be 'competing demands' for spectrum from non-government service providers, particularly spectrum for public mobile telecoms services, unless there are overriding public policy reasons to do otherwise. When the CA considers that there are unlikely to be competing demands, spectrum is assigned administratively. This includes spectrum for fixed links, Electronic News Gathering/Outside Broadcast (ENG/OB) links, satellite uplinks, private mobile radio systems, most of which are occupied and used on a shared basis by many users. Spectrum trading is likely to be less relevant to spectrum with no competing demands.

The focus of this study is to advise on the benefits and costs of introducing a spectrum trading regime in Hong Kong for spectrum with competing demands that has been predominately assigned by market-based mechanisms, mainly spectrum for public mobile telecoms services. We also note that spectrum trading has been or is being implemented in some international advanced markets alongside other market-based spectrum assignment mechanisms.

1.2 Structure of document

The remainder of this document is laid out as follows:

- Section 2 provides an overview on the latest international spectrum trading developments
- Section 3 provides an assessment of supply of and demand for spectrum for trading in Hong Kong based on current market practices and landscape
- Section 4 provides an evaluation and analysis of the costs and benefits of introducing a spectrum trading regime in Hong Kong
- Section 5 proposes an approach to introducing a spectrum trading regime should one be introduced in Hong Kong; it also recommends alternative mechanisms to enhance the efficient use of spectrum if a trading regime is not pursued
- Section 6 provides a summary of our conclusions.

The report includes several annexes containing supplementary material:

- Annex A presents case studies of markets with a clear spectrum trading regime (Category 1)

- Annex B presents case studies of markets where spectrum trading is possible, albeit not through a full-fledged trading regime (Category 2)
- Annex C presents case studies of markets where no spectrum trading is possible (Category 3)
- Annex D presents a quantitative impact assessment of spectrum trading on market outcomes
- Annex E presents the interview questions asked to industry players on spectrum trading and the list of stakeholders interviewed
- Annex F presents the responses of industry stakeholders interviewed
- Annex G provides a mobile spectrum map of Hong Kong.

2 Overview of the latest overseas experience in respect of spectrum trading

Spectrum trading is one of the many tools used by regulators to manage radio spectrum. It provides a mechanism through which a party's right to use spectrum can be transferred to another party outside of primary assignments, via a secondary market mechanism. First used in New Zealand in 1989, spectrum trading has been implemented to varying degrees in several jurisdictions worldwide, with the objectives of improving access to spectrum, broadening spectrum use, increasing flexibility in spectrum use and increasing overall spectrum efficiency. However, there remain some markets where spectrum trading is either not yet implemented or not allowed.

In this section, we draw on international case studies to explore the definition of spectrum trading and understand the benefits and costs on spectrum trading.

2.1 Defining spectrum trading

'Spectrum trading' has different interpretations in different markets. In some cases, it is used interchangeably with the term 'spectrum transfer' to describe a general transfer of spectrum permissions between two separate parties, while other jurisdictions have gone further to define a set of rules and regulations for spectrum trading. The International Telecommunication Union (ITU) defines spectrum trading as follows:

> "*Spectrum trading, or the transfer of Spectrum User Rights, denotes a mechanism whereby rights of use are transferred from one user to another for a certain price. In contrast to a system in which spectrum is returned to the regulator and then re-assigned, the trading approach is characterized by:*
>
> - *Transfers of rights are initiated voluntarily by the present user;*
> - *The sum paid by the new owner of the Spectrum User Rights is retained, in full or in part, by the previous owner.*"
>
> **ITU, 2006**

In some jurisdictions, spectrum trading has not been explicitly mentioned, but the transfer of spectrum holdings involving monetary exchanges is allowed. For example, in Switzerland the Telecommunications Act Article 24d paragraph 1 specifies that spectrum licences "*may be transferred in part or as a whole to a third party only with the consent of the licensing authority.*

This also applies to the economic transfer of the licence." [3] This suggests that monetary exchanges are permitted in spectrum transfers.

Some jurisdictions loosely define what is permitted under spectrum trading, i.e. European Commission (EC)'s communication code regulated that "*Member States shall ensure that undertakings may transfer or lease to other undertakings in accordance with conditions attached to the rights of use of radio spectrum and national procedures individual rights of use of radio frequencies*"[4]. Each member state thus has considerable freedom to design a suitable spectrum trading framework for itself. Some European Union (EU) jurisdictions like Luxembourg amended their laws to make possible the transfer of rights of spectrum use but stopped short of further defining what is allowed in their spectrum trading regimes.

Other jurisdictions go further in their definition of spectrum trading, specifying various forms of trading allowed in their respective markets, including full or partial trading and spectrum leasing. Ofcom in the UK describes spectrum trading as, "*the ability to sell and buy access to radio spectrum within the overall terms of the original assignment. Spectrum trading is a generic term that encompasses both spectrum transfer, which is currently allowed under spectrum trading regulations, and a new process of spectrum leasing"*.[5] The Ofcom statement also implies that asymmetrical trades involving monetary transfers are permitted, and the ITU statement above also refers to monetary transfers.

From the above, spectrum trading is generally specified as a market-based mechanism with clearly defined rules and regulations to detail the scope and processes for trade. In many jurisdictions, spectrum trading has often been introduced together with regulations to give licensees more flexibility to reconfigure their spectrum holdings in certain circumstances. Monetary transfers are also permitted under a spectrum trading regime. In some jurisdictions, spectrum trading has not been explicitly permitted, but spectrum may be transferred with monetary exchange.

For the purposes of this document, jurisdictions where monetary exchanges are allowed with spectrum transfers will be considered to allow spectrum trading, irrespective of whether a formal spectrum trading regime has been put in place or not.

Drawing on international case studies (for the full case studies, please refer to Annex A, Annex B and Annex C), we have identified three major scenarios with respect to the implementation (or otherwise) of spectrum trading, namely:

- Category 1: Clear spectrum trading regime

---

3 Source: Telecommunications Act (TCA) of 30 April 1997 (Status as of 1 January 2018), Chapter 3 Radiocommunications, Art. 24d Transfer of the licence, The Federal Council of the Swiss Confederation

4 Source: Directive 2009/140/EC of the European Parliament and of the Council of 25 November 2009, Article 9b Transfer or lease of individual rights to use radio frequencies, European Parliament

5 Source: Simplifying spectrum trading: Reforming the spectrum trading process and introducing spectrum leasing, Ofcom, Mar 2010.

- Category 2: Spectrum trading is possible, albeit not through a full-fledged trading regime
- Category 3: No spectrum trading is possible.

In Hong Kong, spectrum trading is not allowed, putting it in Category 3. Having said that, a party can gain access to the spectrum held by an operator by acquiring that party through M&A activity, subject to the relevant provisions in the Competition Ordinance (CO)[6] (Cap. 619). The CA may also approve, on a case-by-case basis, operators' requests to swap spectrum, where no monetary exchanges can take place. We discuss the existing regulatory regime in Hong Kong in more detail in Section 3.1.

2.1.1 Category 1: Clear spectrum trading regime

Main characteristics

Aside from explicitly permitting spectrum trading in the relevant telecoms laws, there are distinct frameworks that clearly define the scope of spectrum trading, including the spectrum eligible to be traded, forms of spectrum trading allowed (full, partial, leasing, sharing) and the permissibility of change-of-use.

The processes for completing trades are also clearly defined, specifically in markets where no involvement by the regulator is required to complete certain types of trade. In markets where ex-ante review is required, the framework includes guidance on how the national regulatory agencies (NRAs) will determine whether a proposed transfer should be permitted, including when a competition assessment will be required. NRAs will also provide a timeline on when to expect a decision on the requested trade.

Setting up clear legislation and frameworks for spectrum trading typically requires significant effort and commitment. For example, the UK implemented a detailed spectrum trading framework in 2004,[7] six years after Ofcom initially expressed its desire to formalise a spectrum trading regime and sought input from stakeholders through consultations.[8]

Variability on the scope of the trading regime

Markets with clear spectrum trading regimes have varying approaches to spectrum trading:

- **Total or partial spectrum transfer**: Transfer of spectrum from one licensee to another, existing or new, licensee. A total spectrum transfer implies the total spectrum holding is transferred from one party to another, including full transfer of the rights of use and obligations for use of that spectrum contained in the original licence. A partial transfer involves the transfer of a portion

6 The Competition Ordnance is an ex-post cross-sectoral competition law that has been fully implemented in Hong Kong since December 2015.

7 Source: A Statement on Spectrum Trading: Implementation in 2004 and beyond, Ofcom, August 2004.

8 Source: Spectrum Trading Consultation, Ofcom, November 2003.

of licensed spectrum from one party to another (including transfer of rights and obligations attached to the transferred part of the spectrum). All case study markets permit both total and partial spectrum transfer.

- **Service neutrality**: Many Category 1 markets (e.g. New Zealand, the USA, the UK) show a cautious approach towards spectrum liberalisation: change of spectrum *use* requires regulatory approvals before any change in the service can be made within existing spectrum rights. However, some markets intend for some licences to be service-neutral to the extent possible to give maximum flexibility to the licensees. In such circumstances, change of service is permitted if it remains within the applicable technical framework (e.g. Australia[9]). There are also markets where service neutrality is band-specific, e.g. in Canada, spectrum in the 24GHz and 38GHz bands was auctioned with service neutrality as the NRA deemed these bands to have a variety of different potential uses with different business plans and technologies that could be employed.[10] Having said that, it should be noted that, for spectrum which can be deployed for public mobile services, once a mobile network operator (MNO) acquires such spectrum, it is uncommon that it will deploy the spectrum for provision of non-mobile services. As such, if the NRA adopts a technology-neutral approach, it will achieve the purpose of giving maximum flexibility to MNOs to employ the latest technologies for their mobile services to meet their business needs.

- **Technology neutrality**: Most Category 1 markets adopt a technology-neutral approach, where licensees are free to determine which technologies to adopt within specified technical parameters. In New Zealand, however, there were cases where technology neutrality of spectrum permissions had been limited by lot design, which favoured one technology (TDD, which required unpaired bands) over another (FDD, which required paired bands). In such cases, regulatory approval was required to amend licensing conditions where licensees wanted to adopt the technology.[11]

- **Leasing**: This is a sub-set of spectrum trading (outright or concurrent), meaning transfer of spectrum for a period shorter than the remaining licence duration. This means the spectrum trade is time-limited (and upon expiry of the agreed term, the rights and obligations return to the original licensee for the remaining duration of the licence). In several advanced markets (as shown in Figure 2.1) where spectrum trading has been enabled, time-limited trades are also permitted. Trading based on time-limited leases might involve different approaches to

9 Source: Australian spectrum management principles, ACMA website. Retrieved from https://www.acma.gov.au/Industry/Spectrum/Spectrum-planning/About-spectrum-planning/australian-spectrum-management-principles-spectrum-planning-acma.

10 Source: Policy and Licensing Procedures for the Auction of the 24 and 38GHz Frequency Bands, Industry Canada, May 1999.

11 Source: 3.5GHz – Allowing greater use of TDD Decision Document, Radio Spectrum Management (RSM), June 2015.

implementation compared to markets where spectrum can be traded in frequency or in geography but without sub-dividing the licence term.[12]

- **Bands**: All case study markets with spectrum trading regimes allow spectrum for public mobile and fixed wireless access to be traded. Historically, spectrum in bands suitable for mobile and fixed wireless access services often faced excess demand, and therefore theoretically, could benefit the most from spectrum trading. However, trading volume for mobile spectrum has so far been quite low, except in Canada and the USA, where regional spectrum licensing provided a strong incentive for trading to harmonise spectrum holdings.

- **Monetary transfer**: Monetary exchange between parties is permitted in spectrum trades (including total and partial transfer, spectrum leasing), and monetary payments can compensate for asymmetric trades of spectrum.

- **Regulatory pre-approval**: There are two major approaches to the notification of spectrum trades, either with or without an ex-ante review:

  ► *Spectrum trades that require ex-ante review*

  In such cases, the spectrum trading process is subject to a preliminary assessment and potentially a second assessment requiring more regulatory attention owing to concerns about potential distortion of competition.

  In the preliminary phase, each prospective trade is assessed based on predefined factors (typically including market share, spectrum holding concentration and impact on market outcomes). In some jurisdictions, the NRA will invite third parties to submit details of any competition concerns once notification of trade is received. Trades that are not expected to cause significant distortion of competition will be approved in this phase. NRAs typically expect to complete the initial assessment within 20 to 35 days.

  If the preliminary phase finds evidence of possible distortion of competition, or violations of restrictions, further assessment is required. NRAs will supplement their initial assessment with more analysis and evidence from the trade deal participants and third-parties and involve the competition authorities. This process can take between 21 days (in USA[13]) to 12 weeks (in Canada[14]).

  Once the trade is approved by the NRA, the transfer can be executed, and the registry of spectrum information will be updated.

---

12 Several markets such as in Europe (e.g. the UK) initially implemented trading without allowing trading in time, before making revised legislation to enable more flexible trading, including time-limited leases.

13 Source: Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets, FCC, October 2008.

14 Source: Framework Relating to Transfers, Divisions and Subordinate Licensing of Spectrum Licences for Commercial Mobile Spectrum, Industry Canada, June 2013.

► *Spectrum trades that do not require ex-ante review*

In jurisdictions that do not require ex-ante review (Australia and New Zealand), the following mechanism is used:

1. Trades are negotiated directly via bilateral agreements, or indirectly via brokers (typically spectrum trading consultancies).
2. Both parties notify the NRA on the spectrum traded or leased once agreement is reached, either through a form or directly to the register. The NRA typically does not require disclosure of the transaction amount, if any.
3. Trades are completed when the register for spectrum is updated.

In these jurisdictions, the NRA is likely to have flexibility to demand ex-ante review of trades for certain spectrum permission. This is typically included as a licensing condition of the spectrum permission. In such circumstances, the regulatory review is typically completed within a single phase.

- **Competition law/guidelines**: As spectrum trading may raise concerns about over concentration of spectrum, competition law/guidelines are in place in all case study markets to address possible anti-competitive practices.

A summary of the features in various spectrum trading regimes is presented in Figure 2.1.

Figure 2.1: Features of spectrum trading regimes of markets in Category 1 [Source: Analysys Mason, 2018]

Market	Total and partial transfer	Service neutral	Technology neutral	Leasing	Mobile/ fixed spectrum	Other spectrum	Monetary transfer	Regulatory pre-approval	Competition law/ guidelines
Australia	✓	✓	✓	✓	✓	✓	✓	✗ 15	✓
Canada	✓	Δ	✓	✓	✓	✗	✓	✓	✓
New Zealand	✓	✗	Δ	✓	✓	✓	✓	✗ 15	✓
UK	✓	Δ	✓	✓	✓	✓	✓	✓	✓
USA	✓	✗	✓	✓	✓	✓	✓	✓ 16	✓

Legend:

✓ – Clearly defined in law or spectrum permission/spectrum licences

Δ – Band-specific

✗ – Not required /not allowed unless regulatory consent given

15 In cases where regulatory pre-approval is not required, the regulator holds ex-post authority to investigate the trade.

16 The USA allows some trades involving spectrum to be approved without regulatory pre-approval. This includes trades that do not raise potential concerns relating to eligibility, use and foreign ownership restrictions and/ or cause acquirer of spectrum to exceed spectrum concentration limit of 10%. There exist ex-post mechanisms to re-examine the trade if any third-party petitions to deny the trade within 30 days of its approval.

Volume of trade

There are varying degrees of trade intensity in markets with clear spectrum trading frameworks. The variances are likely due to the general spectrum management frameworks adopted in each market described in Figure 2.2.

Trades for mobile spectrum have remained low in most case study markets, except for Canada and USA where higher volume of trades occurs, largely attributed to their regional spectrum licensing regimes.

Spectrum holdings can be transferred as part of M&A activity, but this should not be regarded as a true form of spectrum trade, as the spectrum is only one element of the assets and liabilities being acquired. Merger control regimes have been developed in most jurisdictions worldwide to separately review and regulate M&A activities.

Nonetheless, some transactions have been prompted between a party taking part in a M&A process and an unrelated third party because of enforcement of competition laws. This is triggered by the competition authority or NRA requiring divestiture of spectrum assets to prevent distortion of competition in downstream markets potentially brought about by the M&A. In such circumstances, although transfer of spectrum between two parties is strictly a result of enforcement of competition laws regarding the M&A proceedings, the transfer of spectrum to a third party is nonetheless enabled by the spectrum trading mechanism. In such cases, the seller of the spectrum may receive monetary compensation from the trade, instead of having the spectrum returned to the NRA without monetary compensation. We consider such transactions to be a form of spectrum trade.

Figure 2.2: Summary status of markets with spectrum trading framework [Source: Analysys Mason, 2018]

Market	Year of implementation	Level of activity	Remarks
Australia	1992	Low	• One notable trade triggered by the underutilisation of 2.5 and 3.5GHz spectrum • Low level of activity due to lack of certainty on licence tenure and limited homogeneity of licences[17]
Canada	1999	High	• High activity due to regional licence trading for harmonised spectrum
New Zealand	1989	Low	• Two notable trades, triggered because of M&A proceedings and when spectrum is underutilised (e.g. WiMAX) respectively • Low levels of activity attributed to small market size, high entry barriers to mobile telecoms services and availability of alternative spectrum that is administratively assigned

17 Source: Spectrum review, Australia Government Department of Communications, March 2015.

Market	Year of implementation	Level of activity	Remarks
UK	2005	Low	• Limited trades involving mobile spectrum, including one case prompted by M&A activity and another case due to change in service of the L-band spectrum
USA	1996[18]	High	• Spectrum licences are typically 'perpetual' in the USA. As most mobile spectrum has already been released by the NRA, the secondary market becomes the only source of spectrum • High trading activity for mobile spectrum as operators trade regional licences to attain harmonised spectrum

As noted in Figure 2.2 above, trading activities in several Category 1 markets have been low, despite trading being introduced several years ago. There could be several reasons for this, for example:

- As Figure 2.2 indicates, trading activities have been highest in Canada and the USA, where it is common for public mobile telecoms licences to be awarded in regionally-specific frequency lots. The regional nature of licensing in these markets is likely to have increased trading activities, since operators might use the secondary market as a means of expanding into other regions, offloading frequencies in regions not required, and aligning frequency assignments between neighbouring licensed regions with a view to simplifying equipment procurement, network deployment and frequency co-ordination.

- In the other markets indicated in the table above, there are several factors that could explain lower than expected levels of trading activity. Proactive release of new spectrum for public mobile use by the national regulator in these markets might have reduced demand for trading (since the supply of frequencies by the regulator has been sufficient to meet demand at that point in time and, when additional spectrum is needed, the regulator has been able to release further new bands). It is also noted that spectrum trading might be encouraged through greater flexibility in licence conditions (i.e. technology and service neutral licensing). This increased flexibility has typically been implemented in recent years but might not have been in place when trading was initially implemented. In addition, (potential) market players may be deterred by the process of acquiring spectrum via trade, as negotiation with incumbent/ established players takes time and gives rise to transaction costs. Also, in a competitive market where spectrum is generally well-utilised, the willingness of existing MNOs to trade spectrum is likely to be low.

[18] Spectrum transfers have been permitted since 1996, but a full-fledged spectrum trading regime was only introduced in 2003.

2.1.2 Category 2: Spectrum trading is possible, albeit not through a full-fledged trading regime

Main characteristics

Markets in Category 2 typically have clauses in their telecoms legislations to permit spectrum trading if the NRA grants explicit approval. There are instances where spectrum licences/permissions contain covenants that explicitly permit spectrum transfer (e.g. in Luxembourg); whereas in some cases the right to trade is explicitly prohibited unless written approval from the regulator is obtained (e.g. in Singapore[19]). In both instances, monetary exchange for spectrum is generally allowed.

However, the ministry or NRA typically stops short of prescribing a framework or guidelines for the scope of transfers, procedures involved and criteria that should be adhered to when assessing a transfer.

As there is no clear spectrum trading framework defined to supplement the law, the NRA will have to review each proposed transfer on a case-by-case basis and interpret as needed. Ex-ante approval is thus necessary for all spectrum trades.

Variability of the scope of spectrum trading

As a case-by-case approach is adopted to assess spectrum trading, there is some ambiguity on what is permitted and what is not permitted. We have used published decisions on previous trades to provide an indication on the scope of spectrum trading permitted in the jurisdiction.

In general, Luxembourg's spectrum trading regime is more defined than those of Switzerland and Singapore, as it is part of the EU and thus regulated under directives from the European Commission. NRAs in Singapore and Switzerland in turn have more flexibility in decisions regarding spectrum trading, as they are not bound by legislation or frameworks (although they may be limited by precedence from past decisions).

The scope of spectrum trading in Category 2 markets is as follows:

- **Total or partial spectrum transfer**: Spectrum can be traded in full or in parts in all case study markets.
- **Service neutrality**: Like the Category 1 markets, most jurisdictions show a cautious approach towards spectrum liberalisation. In Luxembourg, in bands harmonised by Radio Spectrum Policy Group (RSPG), licences clearly indicate spectrum to be transferable, service- and

[19] With the exception of the 2016 auction for the fourth mobile operator in Singapore, where the NRA specifically restricted its approval of spectrum transfer to M&A scenarios. Source: Auction Of 700MHz Spectrum Rights (2016), 900MHz Spectrum Rights (2016), 2.3GHz Spectrum Rights (2016) And 2.5GHz Spectrum Rights (2016), Information memorandum, Info-communications Development Authority (IDA) Singapore, April 2016.

technology-neutral within specified technical parameters,[20] which effectively limits the scope of technology and services that can be offered in the spectrum band. However, in bands not harmonised by the RSPG, the NRA provides no indication if similar conditions will apply.

- **Technology neutrality**: Markets in Category 2 also adopt a technology-neutral approach, where licensees are free to determine which technologies to adopt and can adjust to market conditions.
- **Leasing**: There is no precedence on spectrum leasing in the public domain for any of the three case study markets.
- **Bands**: Luxembourg licences explicitly permit mobile and/or fixed wireless spectrum to be transferrable;[21] while for Singapore and Switzerland, NRAs have approved spectrum transfers in such bands on a case-by-case basis.
- **Monetary transfer**: Although transfers are explicitly permitted, there is no precedence of a monetary transfer in Luxembourg. By contrast, the Singapore NRA has permitted monetary compensation for spectrum transfer.
- **Regulatory pre-approval**: Regulatory pre-approval is required for spectrum trades in all Category 2 markets. However, the process and approval criteria for the regulatory approval for spectrum trading is typically not defined. Typically, parties to the transfer deal will notify NRAs of their intention, and NRAs may then conduct an internal review, or seek inputs from affected third parties through public consultations. The decision made is then published and the register of spectrum is updated. There can be considerable variation to the above process to the discretion of each NRA.
- **Competition law/guidelines**: Competition law/guidelines are in place in all case study markets to address possible anti-competitive practices (e.g. over-concentration and hoarding).

---

20 Source: Frequency register, ILR. Retrieved from: https://web.ilr.lu/FR/Professionnels/Frequences-radioelectriques/Utilisation-de-frequences/Registre-des-frequences/Pages/default.aspx (in French).

21 Source: Frequency register, ILR. Retrieved from: https://web.ilr.lu/FR/Professionnels/Frequences-radioelectriques/Utilisation-de-frequences/Registre-des-frequences/Pages/default.aspx (in French).

Figure 2.3: Features of spectrum trading regimes of markets in Category 2 [Source: Analysys Mason, 2018]

Market	Total and partial transfer	Service neutral	Technology neutral	Leasing	Mobile/ fixed spectrum	Other spectrum	Monetary transfer	Regulatory pre-approval	Competition law/ guidelines
Luxembourg	✓	✓	✓	Δ	✓	Δ	Δ	✓	✓
Singapore	✓	Δ	✓	Δ	○	Δ	○	✓	✓
Switzerland	✓	Δ	✓	Δ	○	Δ	Δ	✓	✓

Legend:

✓ – Clearly defined in spectrum permission/spectrum licences

○ – With precedence

Δ – Not clearly defined and with no precedence

Volume of transfers

Category 2 markets experience low levels of spectrum trading. This is described in Figure 2.4 below for mobile spectrum specifically.

Figure 2.4: Summary status of markets that permit spectrum trading [Source: Analysys Mason, 2018]

Market	Level of activity	Remarks
Luxembourg	Nil	• No proposed transfers have been published by the regulator • Lack of competing services for commercial mobile spectrum could have decreased the need for spectrum transfer
Singapore	Low	• Spectrum transfer is triggered by underutilisation of WBA spectrum. Monetary compensation is involved
Switzerland	Nil	• No transfers have been published by the regulator

In Singapore and Switzerland, where spectrum trading is not formalised, NRAs do not rely entirely on spectrum trading to correct spectrum inefficiency. Instead they employ alternative mechanisms to encourage efficient spectrum use, such as using a rigorous primary assignment process and ensuring general availability of spectrum through auctions. This might also be a contributing factor to low demand for spectrum trading.

2.1.3 Category 3: No spectrum trading is possible

Main characteristics

Spectrum trading, whether in whole or in part, is not allowed in markets in this category (notably Japan and Mainland China). The transfer of spectrum in a limited set of scenarios (e.g. because of M&A) has been permitted.

Implementation

In markets that do not permit spectrum trading, NRAs usually take a more proactive role in managing spectrum utilisation and efficiency. Examples from our case study markets show that NRAs could adapt licencing rules and frameworks to suit a default non-trading stance, and could also review prospective transfers in a limited set of scenarios to achieve the similar objectives of promoting the efficient use of spectrum.

- *Corrective measures on inefficient spectrum use*

In markets that explicitly prohibit spectrum trading, the onus is on NRAs to decide to correct any inefficient spectrum use.

In Japan, the Ministry of Internal Affairs and Communications (MIC) will undertake detailed planning to implement spectrum re-assignment. MIC has come up with detailed action plans to re-

assign and harmonise frequencies bands have been used in Japan for a proprietary use that does not align with international harmonisation.[22]

- *Adapting licencing rules and frameworks*

In markets that do not allow spectrum trading, the primary assignment process becomes more vital in ensuring that the use of spectrum is efficient over time. Licensing rules and frameworks will thus need to be adapted to allow for more flexibility following primary assignment, and licence durations are generally shorter than in markets where spectrum trading facilitates the adjustment of spectrum holdings to changes in the market, and where licences might be perpetual (e.g. as in the recent licensing decisions on mobile spectrum in UK, and in the USA) or have a long duration (e.g. up to 20 years in Canada). Shorter licence durations give the NRA more control of spectrum assignment, allowing them to correct any market inefficiencies within the shorter renewal cycles.

For example, in Japan the Radio Law states that "*[t]he validity period of licenses for radio stations shall be specified in the applicable MIC ordinance [Article 7 through 9] within five years calculated from the day of a license granted. However, renewal may be allowed.*" [23] MIC therefore could undertake assessments at five-year intervals to confirm spectrum has been effectively utilised, on top of awarding spectrum permissions based on detailed deployment plans. However, we note that MIC does not appear to revoke or deny request of renewal of spectrum by spectrum users, particularly for mobile commercial spectrum given the high capital outlay required to build the networks.

In Mainland China, the NRA has the right, given by the law, to re-assign spectrum or take back assigned spectrum after negotiation with the assignees if the current spectrum assignment is deemed inefficient. Mainland China had previously assigned spectrum in the 1900MHz band for use by personal handy-phone systems (PHS), but ordered its cancellation in 2011.[24] China Unicom and China Telecom returned the spectrum, and it was re-assigned to China Mobile in 2013 for 4G use.

- *Case-by-case approvals of spectrum transfer under special circumstances*

Although spectrum trading is not permitted in general, some NRAs allow transfers of spectrum under special circumstances.

In Mainland China, the default stance of the NRA is that spectrum cannot be transferred or leased. Change of use of spectrum is also not permitted. Nonetheless, parties that are interested in exchanging spectrum may seek approval from the relevant state or federal authorities. However, there is no successful case of spectrum transfer available in the public domain.

---

22 Source: Revised Action Plan for Spectrum Reallocation, MIC, October 2012.

23 Source: Radio Law, 2017, Japan, Article 6, 13.

24 Source: Unicom to shut down PHS service, TeleGeography, Jul 2013. Retrieved from: https://www.telegeography.com/products/commsupdate/articles/2013/07/25/unicom-to-shut-down-phs-service/.

A narrow set of spectrum transfer scenarios is allowed explicitly in Japan. Transfer of licences is permitted as part of a going concern. Licences can change ownership in a merger or inheritance scenario, with the inheritor required to fulfil the requisite conditions under the licence. Japan also permits licences to be transferred as part of corporate restructuring, e.g. when a corporation is divided into one or more corporations, one of the new successor corporations can take over the spectrum licence with the permission of the NRA.[25]

2.2 Benefits of spectrum trading

Spectrum trading is one of the mechanisms aimed at improving the use of spectrum, and/or facilitating more efficient market-based exchanges of spectrum.

Theoretically, the introduction of secondary markets for spectrum exposes the opportunity cost of holding spectrum to the licensees, providing incentives for the spectrum to be used and/or made it available to other users. A secondary market with high volumes of trading can increase the transparency in the value of spectrum, enhancing awareness of market entry opportunities.

Spectrum trading is often applied markets as a complementary mechanism to market-based primary assignments, as it provides additional flexibility for the market to re-distribute spectrum resources as and when opportunities for more efficient use arise and transfers may be needed to enhance the efficiency of spectrum use. Benefits from the improved efficiency of use may arise from the following sources:

- aggregation of regional spectrum holdings
- rejuvenation of underutilised spectrum
- lowering barriers to expansion
- flexibility to allow spectrum use to evolve with changing market demands
- additional incentives to change the use of spectrum in regimes with perpetual licensing
- reduction of administrative burden on the regulator under specific regulatory context.

2.2.1 Aggregation of regional spectrum holdings

In markets where spectrum is routinely assigned as regional rather than national licences, spectrum trading can enable operators to aggregate regional holdings into a national footprint so that the same spectrum can be deployed by an operator across a wider (national) coverage area. This is because the complexity of a primary assignment divided into many regions may sometimes not achieve a fully optimal outcome.

Regional licensing is typically employed in large geographical markets such as the USA and Canada, with the objective to allow sub-national operators to have access to spectrum and increase competition in the market at the regional level. However, as spectrum permissions are regionally

[25] Source: Radio Law, 2017, Article 20.

divided, there is a possibility that the primary assignment might result in operators having fragmented spectrum holdings. Spectrum trading thus becomes a useful tool to harmonise regional spectrum holdings and allow operators to hold more contiguous spectrum.

In the USA, Verizon traded 23 regional blocks of spectrum in the 700MHz band to T-Mobile, in exchange for 19 blocks of AWS band, 8 blocks of PCS band, and USD2.4 billion. This trade, combined with existing spectrum, allowed T-Mobile to hold 700MHz spectrum in nine out of the top ten US regional markets. It also allowed Verizon to achieve more contiguous spectrum and allowed it to expand its LTE deployment in the USA.

In Canada, Telus has also used spectrum trading to swap its 3500MHz fixed wireless access spectrum licences with Xplornet, a regional ISP, in exchange for its 2300MHz spectrum licences in similar regions. The trade allowed Telus to have 2300MHz spectrum in nearly every market in Canada, and it can build on its ecosystem of network infrastructure and devices to provide more robust mobile and fixed wireless broadband access to its users.

2.2.2 Rejuvenation of underutilised spectrum

In instances where assigned spectrum does not end up being fully utilised by the licence holder, spectrum trading is a way in which the underutilised spectrum can be transferred – in whole or in part – to another market player. By doing so, underutilised spectrum may be rejuvenated and transferred to better use (assuming efficiency is achieved if spectrum is assigned to the use for which the valuation is the highest).

As an example, in 2009 the NRA in Singapore approved the transfer of Pacnet Internet Corporation's WBA spectrum and facilities-based operator licence rights to Packet One (P1) for USD2.04 million. P1 intended to use the previously dormant spectrum to provide supplementary bandwidth to MNOs.

New entrants often acquire spectrum with the intention of rolling out a regional or national network. However, various issues including changes in business strategy and lack of funding may put plans on hold, leaving spectrum underutilised. Even though some licence conditions come with 'use-it-or-lose-it' regulations, spectrum trading may facilitate the rejuvenation of such underutilised spectrum before such obligations kick in. Even in the case where underutilised spectrum must be returned to the NRA under 'use-it-or-lose-it' provisions, a substantial amount of time may pass before such returned spectrum is re-allocated (e.g. as part of the next primary assignment process).

In New Zealand, Woosh Wireless, an Auckland-based wireless broadband operator, had acquired spectrum in the 2.3GHz band with the intention to bid for New Zealand's Rural Broadband Initiative in 2007. However, the spectrum had been left unused after Woosh had lost the bid to provide broadband services for the Rural Broadband Initiative. The secondary market mechanism enabled the incumbent Spark to acquire rights for this underutilised spectrum from Woosh and another FWA operator, Craig Wireless, to expand its fixed-wireless offering.

2.2.3 Lowering barriers to expansion

Various NRAs that have implemented a clear spectrum trading regime have suggested that, theoretically, trading enables existing operators to expand their networks more quickly than would be the case without trading.[26]

This is primarily because opportunities for trading are always in place i.e. can occur as and when needed, whereas primary assignments of spectrum (e.g. auctions) are timetabled to occur at specific times in line with the NRA's plans.

Our assessment of markets in Category 1 suggests that spectrum trading has allowed the expansion of an operator's geographical coverage in between primary assignments. For example, Leap Wireless's 4G launch in Chicago was facilitated through a spectrum trading deal with Verizon in 2011, when Leap acquired 12MHz of 700MHz spectrum covering Chicago in exchange for over 36 blocks of AWS and PCS bands across 16 states. Leap has previously announced that it "lacks sufficient depth" to launch LTE services in the Chicago area.[27] The deal enabled Leap to receive net cash proceeds of more than USD100 million, allowing it to support ongoing deployment of LTE network technology.[28] The deal also helped release Leap from the roll-out commitment of its unused licences. This allowed Leap to grow to become the fifth largest operator in the US market, before eventually being acquired by AT&T in 2014.

2.2.4 Flexibility to allow spectrum use to evolve with changing market demands

Primary spectrum awards take place at points in time determined by the NRAs, taking account of market demand, as well as overarching spectrum release plans that also reflect the expiry of existing licences. This means that the availability of spectrum and the opportunities to change spectrum use may not be well aligned with the rapid pace of technology development in the wireless market.

Regimes with long licence durations (more than 20 years, or perpetual licences) offer certain benefits in terms of providing greater certainty and thus better incentives for making potentially large, sunk investments in network infrastructure. A key disadvantage of this is that the rapid pace of change in the telecoms industry may quickly leave the (previously efficient) assignment and use of spectrum outdated. Changing technology and service demands may develop in a way that is not in line with licence expiry and the opportunity to re-assign spectrum through primary awards. As a result, there may be lags in responding to market and technology changes, which could hamper technological innovation and delay the deployment of new technologies or improved services.

---

26 ERG-RSPG (2009) study.

27 Source: @ CTIA: Leap set to launch LTE this year, signs roaming deal with LightSquared, RCRWirelessNews, March 2011.

28 Source: Press release by Leap Wireless, "*Leap Enters into Spectrum Transactions with Verizon Wireless*". Retrieved from: http://www.prnewswire.com/news-releases/leap-enters-into-spectrum-transactions-with-verizon-wireless-135050128.html.

Spectrum trading provides increased flexibility for accommodating changes in market demand, or deployment of new technologies, as it can enable existing operators to dispose of spectrum that is no longer needed, or acquire new spectrum in the necessary increments, and use it to expand services or roll out new technology and services. If this newly acquired spectrum reduces the amount of infrastructure deployment required, it can facilitate cost reductions for operators, allowing faster and broader roll-outs. For operators disposing of spectrum, there will be reduction in cost from having less spectrum deployed. The correction in spectrum assignment through a market-based system can take place as and when needed, without having to wait for the licence terms to expire or the NRA to take corrective measures.

An example of the role of spectrum trading in allowing spectrum use to evolve with changing market demands and development of new technologies is in the context of operators holding spectrum to deploy WiMAX services. Trading has allowed these operators to rationalise their 2.5GHz and 3.5GHz spectrum holdings when LTE surpassed WiMAX as the dominant technology for mobile and fixed wireless applications in some markets. In Australia, after the purchase of Austar's 2.5GHz and 3.5GHz spectrum holdings, NBN Co rolled out fixed wireless service, using LTE-TDD technology instead of WiMAX.

For MNOs without access to spectrum for LTE deployment or expansion, the existence of trading regimes might have facilitated faster deployment through access to complementary spectrum. There has been significant trading of spectrum suitable for 4G in the USA, which has enabled T-Mobile (which did not obtain spectrum at the 700MHz auction) to launch new 4G services.

In addition, spectrum trading could be a potential mechanism for MNOs to rebalance their spectrum portfolios in face of changing consumer demand for an operator's services, or changes in market structure or competition (i.e. changes in market share). However, based on international experience, we have not generally observed MNOs adopting spectrum trading to rebalance their spectrum portfolios.[29] This can be attributed to the competitive environment in which most case studies markets operate. A scenario where a drastic change in spectrum demand, caused by a significant change in market share, is therefore unlikely to take place.

2.2.5 Additional incentives to change the use of spectrum in regimes with long or perpetual licences

In regimes with long (more than 20 years) or even perpetual licence durations, there is the potential that market conditions have evolved in such a way that a more valuable use of a band of spectrum has emerged. The availability of spectrum trading provides additional incentives to change the use of spectrum to a higher value use, to facilitate trading of spectrum to the party that can extract the

[29] The exception to this is where MNOs have been required to divest spectrum as a result of measures applied by competition authorities in response to mergers e.g. a merger of two MNOs in the UK market resulted in the merged entity releasing spectrum, through trading, to the operator with the least spectrum in the market, to re-balance spectrum holdings. It is also noted that, in the US market, there have been some trades between MNOs to re-balance high and low frequency holdings via spectrum swaps.

greatest value from the spectrum. This is only applicable in regimes where change of service is allowed by the NRA.

For example, in the UK, spectrum in the L-Band was acquired by chipset manufacturer Qualcomm to provide a test bed for the then latest advanced wireless services. However, after the EU harmonised the 1452–1492MHz band for mobile network supplemental downlink (SDL) in May 2015, the spectrum became more valuable for mobile communications purposes. After getting regulatory clearance to change the technical conditions of its L-Band spectrum to suit public mobile purpose, Qualcomm traded its L-Band spectrum licences to MNOs, Three and Vodafone, to allow them to supplement their spectrum holdings and expand their mobile networks.

In the USA, frequencies in bands that are now considered as potential 5G bands (involving spectrum around 26–29GHz) had been released to the market through 1998 auction for 'Local Multipoint Distribution Services' in 1998. As the USA has a perpetual licensing regime, there is no option to re-assign this spectrum upon expiry of a licensing term, and re-assignment relies on market-based mechanisms like spectrum trading. Through such mechanism, MNOs were indeed able to acquire these spectrum assets for 5G, and subsequently petition the FCC for the change-of-use of these high-band frequencies for public mobile service so that they can proceed with 5G launch plans.

2.2.6 Reduction of administrative burden on the NRA under specific regulatory context

Some spectrum management regimes have been established in a way that encourages spectrum transfers to occur, which could otherwise involve significant administrative burden in reviewing changes in spectrum assignments, licence ownership and related transactions on a case-by-case basis. Large numbers of licence transfers could take place when licences are split into regions in the primary assignment and continuous holdings are not amalgamated and managed as a single licence. It is likely that the high volume of transactions that require administrative processing was not anticipated, and existing mechanisms were not built to cope with the large volume of spectrum transfers.

In such regimes, some NRAs have made use of spectrum trading to allow the market to handle these transactions with minimal regulatory interference. This is more relevant to Category 1 markets, with a clear spectrum trading regime.

For example, in the USA, spectrum is auctioned in the form of small regional lots, resulting in large numbers of licences issued in each auction. The FCC has permitted certain spectrum trades (those that do not involve potential violations of use restrictions, foreign ownership restrictions or foreign competition) to be eligible for 'immediate approval process', thereby simplifying the administrative process and assist operators to harmonise their spectrum portfolios in a timely manner.

We note that the benefits of reduced administrative burden apply typically in cases where the administrative effort saved from processing a large volume of transactions is expected to far outweigh the efforts required to develop and implementing a clear spectrum trading regime.

Conversely in regimes where only a limited number of spectrum trading is expected (as would be the case where spectrum trading is limited to mobile spectrum in the absence of regional licensing, where volumes are likely to be low), the administrative efforts saved may not justify the administrative burden involved in implementing and maintaining a clear spectrum trading regime.

We also note that the benefits of reduced administrative burden would not apply in cases where a case by case approval methodology is adopted. In contrary, administrative work would increase as the NRA would need to pay additional efforts in processing the cases. In any event, efforts are required to monitor trading activities to ensure that no competition, interference, harmonisation, etc. concerns will arise.

2.3 Costs of spectrum trading

The rationale for introducing spectrum trading is to improve spectrum use and increase flexibility for market-based spectrum exchanges, as described in the previous section. However, implementing spectrum trading may give rise to potential costs to the NRA and to spectrum users, and careful mitigation will be required from the NRA to safeguard against these negative consequences of spectrum trading. These costs are primarily associated with the following issues:

- spectrum hoarding, including speculative hoarding
- windfall profits and other private profits gained by trading parties
- over-concentration of spectrum leading to foreclosure of competition
- loss of harmonisation
- increased risk of interference
- distortion of auction dynamics.

In regimes with spectrum trading (and in Category 1 markets), it is generally accepted by the NRAs that there are potential costs to spectrum trading implementation and that they need to be managed through a range of safeguards, balancing potentially efficiency losses from discouraged trades against the efficiency gains from avoiding undesirable outcomes.

2.3.1 Spectrum hoarding, including speculative hoarding

A potential cost of spectrum trading is the risk of increased ability to hoard spectrum, where spectrum may be acquired, but left unused or under-utilised. Spectrum hoarding might arise where spectrum is acquired for speculative purposes (i.e. with the sole purpose of reselling for a higher value in the future) or for anti-competitive reasons (i.e. to prevent competitors from gaining access to spectrum). An extreme manifestation of hoarding is where spectrum is being acquired in absence of constructive use being made of it and is left idle. In all cases, hoarding restricts the supply of scarce spectrum resources to the rest of the market for its intended use. This results in the underutilisation of spectrum, to the detriment of other operators and ultimately of consumers, and imposes a social cost on the community.

- *Speculative spectrum hoarding*

There are concerns about the purchase of spectrum for speculative reasons. The speculator believes in the appreciation prospect of the spectrum, and is willing to take the risk of purchasing the spectrum at a price higher than the current value for those who would use the spectrum. The additional costs may potentially be transferred to consumers.

Spectrum trading regimes increase the liquidity of spectrum 'markets' by providing 'speculators' with an exit mechanism other than complete divestment of the spectrum holding company, and can therefore increase the potential for speculative activity.

- *Anti-competitive spectrum hoarding*

Spectrum may be acquired for strategic reasons to foreclose the market. In this case, hoarding is not only wasteful, but also anti-competitive (and lead to over-concentration of spectrum in the hands of few as further discussed in Section 2.3.3). Spectrum trading may facilitate anti-competitive hoarding by providing additional opportunities for strategic acquisition of spectrum.

An anti-competitive hoarder will often use the spectrum to reduce their own costs (i.e. provide additional network capacity or other services), at the expense of its competition. In such cases, proving the case of anti-competitive hoarding of spectrum becomes more difficult as spectrum can be seen to be in use.

2.3.2 Windfall profits and other private profits gained by trading parties

One of the costs/risks that has been raised regarding spectrum trading is the potential for spectrum holders to profit through spectrum trades.

These profits may reflect the value gains that can be achieved from re-deploying spectrum for other uses or for use of new technologies, e.g. because of unanticipated changes in market demand for spectrum or supply of spectrum for uses (technological evolution, for example). It can also be a result of capital gains realised by spectrum holders when spectrum is converted into tradable usage rights after the primary award of spectrum, making the spectrum more valuable. The increased value in these circumstances is often known as 'windfall'.

An example of private profits gained by spectrum holders is Qualcomm's sale of its L-Band spectrum, which it originally purchased for GBP8.3 million. The band was initially reserved for mobile TV usage during the primary award but was harmonised for SDL by the EU, a feature proposed by Qualcomm for enhancing LTE downlink capacity. Ownership of the spectrum gave Qualcomm further incentive to demonstrate the functionality of SDL and push to change the use of the L-Band from broadcasting to LTE purposes. After Qualcomm successfully applied to change the technical conditions for its L-Band to suit public mobile telecoms, it sold the spectrum to Vodafone and Three for an estimated GBP200 million. The profit opportunity for Qualcomm arose as a more valuable use emerged, although Qualcomm appears to have actively contributed to the process to legislate the change of use of L-Band from mobile TV to higher-value LTE purposes.

Profit opportunities may also arise from inefficient primary awards, where an administrative mechanism, or restrictive market-based mechanisms (i.e. auction for new entrants) was used in spectrum assignment. In such cases, the true market value of spectrum was not priced into the initial assignment.

Since spectrum is a valuable and scarce public resource, the public would expect that any financial profits arising from spectrum should be captured by the government (rather than individual MNOs), and subsequently be put into other public services. The introduction of spectrum trading may affect prices paid in primary assignments, which in turn would limit the ability of the government to use the profits arising from spectrum for public purposes. Large profits obtained by MNOs from trading activities may also be deemed as unfair and inequitable by the public.

2.3.3 Over-concentration of spectrum leading to foreclosure of competition

Over-concentration of spectrum may be a result of spectrum hoarding by market incumbents to prevent their competitors from gaining access to spectrum, and/or foreclose the market. This potential cost has been acknowledged by multiple jurisdictions who have implemented spectrum trading, including the EU where, in a 2009 report on radio spectrum competition issues produced by the European Regulators Group (ERG) and Radio Spectrum Policy Group (RSPG), found that *"spectrum trading could lead to over-concentration and/or hoarding of spectrum by a small number of existing operators with the purpose of creating barriers for new-entrants or to restrict expansion by rivals.*[30]*"* This can have direct effects on the downstream markets, especially when the spectrum being hoarded is used to deliver a service in the downstream market that cannot be delivered using another band. For example, if the entire spectrum that can be used to deliver a service on a downstream market is held by one or a small group of players, and there are no alternative/substitutable bands on which this service can be delivered, then new entry into the market becomes impossible, and thus the quality of service to end users suffers.

In this case spectrum will likely not be completely idle as incumbent operators have incentives to make some use of the asset, e.g. by improving and expanding their network to further differentiate their services. However, this is not the most efficient use of spectrum.

Over-concentration of spectrum is however difficult to prove in practice, as there are also legitimate reasons for operators holding apparently excessive amounts of spectrum. For example, an operator might want to hold spectrum to maintain an option to expand capacity, and/or broaden range of services offered in the future. Although there is significant opportunity cost to such a strategy, it is entirely reasonable when there may be an adverse impact on market share if the operator were to run out of capacity,[31] where there is no ready source of spectrum that could be tapped. One cannot

---

30 Source: ERG-RSPG Report on radio spectrum competition issues: management of radio spectrum in order to avoid anticompetitive hoarding, June 2009.

31 Vodafone Australia experienced a significant decrease in the number of Vodafone subscribers between 2010 and 2014 due to its failure to anticipate the growth in the consumer demands which overloaded its network and led to a significant reduction in service quality.

assume that an operator with idle spectrum is engaging in anti-competitive behaviour, where primary awards are the only source of spectrum. Some may hold the view that a spectrum trading regime increases the opportunity costs of excessive spectrum holdings, and removes some of the rationale for incurring them in the first place (namely the need to hold reserves as no alternative source is available), so that holding idle or barely utilised spectrum may be a greater indication of potential anti-competitive conduct in the presence of a trading regime.

2.3.4 Loss of harmonisation

Another potential cost is that spectrum trading can result in a loss of harmonisation (e.g. if a purchaser of spectrum changes the use from a harmonised to a non-harmonised one). Non-harmonised use would normally imply a reduction in the efficiency of spectrum usage (e.g. loss of markets of scale, increase in interference with adjacent, harmonised uses).

In any case, it is worth noting that in the case of a proper regime for interference management (see below), any efficiency loss from non-harmonised use must be outweighed by the efficiency gains from the redeployment of spectrum, as otherwise the acquirer would not be willing to incur the cost of having to comply with emission constraints or the provision of guard bands to comply with the existing obligations.

This is only prevalent when change-of-technology or service, or both is permitted for the spectrum licence/permission.

2.3.5 Increased risk of interference

Spectrum trading poses a risk of interference, if change of services is permitted in a specific band, as this may result in different services being deployed in close spectrum allocations. A report by London Economics[32] points out that change of technology and services can lead to interference between competing technologies and services. A similar opinion is presented in Oxera's report[33] –

> *"[Oxera's] finding is also underpinned by technical considerations given that even small changes in spectrum allocations could trigger concerns about interference."*

If a trade results in a non-harmonised use being implemented in a harmonised band, the risk of interference will also increase, and additional effort and cost is required to protect against such possibilities.

---

32 "Economic Impacts of Increased Flexibility and Liberalisation in European Spectrum Management" – A Report for a group of European communications sector companies, prepared by London Economics (April 2008).

33 Spectrum Trading Issues – Report prepared for ComReg, 2012, by Oxera Consulting LLP.

2.3.6 Distortion of auction dynamics

The existence of a secondary market for spectrum may affect the behaviour of existing MNOs and new entrants, with a bearing on prices paid in primary auctions.

In particular, auction dynamics may become distorted with the knowledge of divestment opportunities in the secondary market for spectrum, and potential windfalls/private profits that may be achieved. A bidder's willingness to pay for spectrum might increase due to 'pricing in' the option value of being able to sell spectrum in the future if profit opportunities were to arise; and/or the reduced risk associated with possibility to regain some of the price paid for the spectrum if the spectrum is ultimately not needed. The effect of this is an upwards pressure on auction prices. High auction prices may have an adverse impact on downstream consumer prices and thus demand on downstream mobile services. High prices may also mean that operators have reduced resources with which to maintain or expand their networks, leading to lower quality of existing or future mobile services. As such, the overall loss of consumer welfare may exceed the gains in government revenue from higher auction receipts.

2.4 Impact assessment of spectrum trading on market outcomes

To study the impact of spectrum trading on market outcomes, we have conducted a basic qualitative and quantitative analysis to check for evidence of the impact of spectrum trading on revenues from primary awards and prices in downstream markets across our case study markets. Our quantitative analysis focuses on Category 1 markets. It makes use of the fact that clear spectrum trading regimes have been introduced at different points in time, which provides us with the opportunity to use data for these different markets covering a period before and after the introduction of trading regimes for our analysis.

A summary of the results of our analysis is as follows (a detailed impact assessment can be found in Annex D):

Revenue from primary awards	Our analysis does not provide any conclusive evidence of a relationship between the introduction of a spectrum trading regime and prices paid for spectrum licences in primary awards (i.e. auctions), as the results of our quantitative study show that the coefficient for trading is neither statistically significant, nor significant in magnitude.
Prices in the downstream market	Results from our statistical analysis are not statistically significant (especially when compared to the effects of market concentration); there is no conclusive evidence of a relationship between spectrum trading and average revenue per user.

3 Supply of and demand for spectrum trading in Hong Kong

Primary spectrum assignment, secondary spectrum trading and market outcomes are inevitably linked. These links are potentially complex and specific to individual markets. Any deliberations on spectrum trading cannot be considered on a standalone basis – it is necessary to understand the wider spectrum management regime and local conditions. In the context of this report, we need to assess the supply of and demand for spectrum trading in Hong Kong.

In this section, we examine the current spectrum management regime in Hong Kong to gain insights on its effectiveness in ensuring optimal spectrum use. We also assess information on the latest market conditions derived from industry interviews.

3.1 The current spectrum management regime in Hong Kong

To understand the implications of spectrum trading for Hong Kong, features of the territory's spectrum management regime will need to be evaluated. These features include spectrum assignment, the typical conditions and obligations of individual spectrum assignees and alternative mechanisms to spectrum trading, and timely release of spectrum for auction.

In the following subsections, we provide a brief discussion of the following features of Hong Kong's current spectrum management regime:

- spectrum assignment
- detailed implementation mechanisms
- the Hong Kong spectrum management framework.

3.1.1 Overall spectrum assignment overview

According to the Radio Spectrum Policy Framework promulgated by the government in 2007, the policy inclination of the government is that "*a market-based approach in spectrum management will be used wherever [the Communications Authority] considers that there are likely to be competing demands from providers of non-government services, unless there are overriding public policy reasons to do otherwise*"[34].

Spectrum for public mobile communications services, currently in the sub-3GHz bands, is usually deemed to have 'competing demands'. A market-based mechanism, typically auctions, is beneficial to assign spectrum to its highest value uses. Spectrum is usually assigned to operators for use for a 15-year term. There is no legitimate expectation that there will be any right of renewal upon the expiry of spectrum assignments at the end of the term.

[34] Source: Radio Spectrum Policy Framework (April 2007), Section 3.1, CEDB

Upon expiry of assignments, the CA will normally re-assign the spectrum concerned via a market-based approach. An exception to a market-based approach for re-assignment is when there are overriding public policy reasons against its adoption (e.g. the need to ensure service continuity). In these circumstances, the CA may deviate from the market-based approach. It may, for example, adopt a hybrid approach for re-assignment, where some spectrum is administratively re-assigned, and some is auctioned in the open market. The CA decided to adopt such an approach in 2013 for the re-assignment of the 1.9–2.2GHz band upon expiry of the assignments in 2016. There were concerns that a full-fledged market-based approach might lead to incumbent 3G operators potentially losing all or parts of their 3G spectrum and/or be assigned spectrum in different frequency sub-bands. This could result in a prolonged period of service degradation, especially during the transitional period post re-assignment in indoor areas. Thus, the CA offered each of the four incumbent 3G operators a right of first refusal to be re-assigned 2×9.9MHz of spectrum (or two thirds of their original spectrum assignments)[35]. The remaining spectrum was made available for auction. In December 2017, the CA decided that a hybrid approach should also be adopted for the re-assignment of spectrum in the 900MHz and 1800MHz bands upon expiry of existing assignments in 2020/21. Using this approach, 40% of the spectrum involved will be administratively re-assigned. The remaining spectrum will be auctioned, with a view to safeguarding the continuity of 4G service provision at Mass Transit Railway (MTR) premises and 2G services across the territory.

Since the promulgation of the Radio Spectrum Policy Framework in 2007, spectrum newly released and re-assigned upon expiry has been made available for auction from time to time. Both incumbent operators and new interested parties can participate in these auctions.

As occurred in the recent re-assignment of spectrum in the 900MHz and 1800MHz bands, when spectrum assignment periods expire, the regulator also re-plans the assignment of spectrum. This is to ensure efficient spectrum block sizes to facilitate the introduction of new technologies and allow operators to make more efficient use of spectrum.

OFCA has held a total of seven spectrum auctions for public mobile services since 2007, one of which concerned re-assignment of spectrum upon expiry of the assignment period. In the case of the re-assignment of the spectrum in the 1.9–2.2GHz band, the spectrum auction was held two years prior to expiry, to allow sufficient time for the MNOs concerned to prepare for the spectrum re-assignment. A similar arrangement will be adopted for the re-assignment of the spectrum in the 900MHz and 1800MHz bands, with the spectrum auction planned to be held around the end of 2018. The spectrum bands that have been assigned through auctions include those shown in Figure 3.1.

35 After the decision was made, the CA gave consent, with conditions imposed, to HKT Limited's (the holding company of HKT) proposed acquisition of CSL New World Mobility Limited (the holding company of CSL). One of the conditions imposed is that the merged entity shall divest a total of 2 x 14.8MHz of spectrum in the 1.9 – 2.2 GHz band by not seeking to renew the assignment of and not acquiring part of the right-of-first-refusal spectrum offered to them.

Figure 3.1: Spectrum released in auctions for public mobile services [Source: OFCA, 2018]

Frequency band (MHz)	Allocation	Auction year	Assignment term	Service type
825–832.5 870–877.5	Mobile	2007	2008–2023	For provision of CDMA2000 services
1780.1–1784.9 1875.1–1879.9	Mobile	2009	2009–2021	For provision of public mobile telecoms services
2500–2515 2540–2570 2620–2635 2660–2690	Fixed Mobile	2009	2009–2024	For provision of broadband wireless access services
832.5–837.5 877.5–882.5 885–890 930–935 2010–2019.7	Mobile	2011	2011–2026	For provision of public mobile telecoms services (spectrum in frequency band 2010–2019.7MHz was not acquired in auction and was placed back in reserve)
2300–2390	Fixed Mobile	2012	2012–2027	For provision of broadband wireless access services
2515–2540 2635–2660	Fixed Mobile	2013	2013–2028	For provision of broadband wireless access services
1920.3–1935.1 1960.0–1969.8 2110.3–2125.1 2150.0–2159.8	Fixed Mobile	2014	2016–2031	For provision of public mobile telecoms services
Spectrum to be released				
890–915 935–960 1710–1720 1730-1740 1770-1785 1805–1815 1825-1835 1865-1880	Fixed Mobile	End 2018 (tentative)	2021–2036	For provision of public mobile or fixed telecoms services
3400-3600[36]	Fixed Mobile	End 2019 (tentative)	2020-2035	For provision of public mobile or fixed telecoms services

In the absence of a formal spectrum trading regime, there is currently no secondary market for spectrum in Hong Kong. Nonetheless, different alternative arrangements that facilitate spectrum transfer are permitted in certain scenarios (this is discussed in more detail in Section 3.1.2). The acquisition of spectrum through M&A activities is also possible.

[36] Consultation on assignment arrangements for spectrum in this band is in process.

In Section 3.1.2, we examine telecoms licensing conditions in Hong Kong to further understand how mobile spectrum is managed to further assess the benefits and costs of introducing a secondary market for spectrum.

3.1.2 Detailed implementation mechanisms

Spectrum as a permission of use

Section 32H (5) of the Telecommunications Ordinance (TO) provides that *"a person shall not … use a frequency in any part of the radio spectrum unless the frequency is assigned, or located within a band of frequencies assigned, by the [Communications] Authority or the use is for the purpose and in compliance with the conditions specified by the [Communications] Authority"*[37]. Spectrum is granted as permission of use in Hong Kong and spectrum assignments form part of the telecoms licences granted to the MNOs, instead of existing as separate and independent licences. Currently, the TO does not have explicit provisions for the CA to issue a licence solely for spectrum permission. Section 32H (2) of the TO empowers the CA to assign bands of frequencies to telecoms service providers and specify the purpose of these frequencies and the conditions in which these frequencies are to be used. These conditions are specified in a schedule that forms part of the telecoms licence held by the MNO.

When new frequency bands are obtained or when spectrum is re-assigned upon expiry, existing MNOs' unified carrier licences (UCLs) will be amended to reflect any changes to their spectrum holdings. A new entrant will have to obtain a UCL that specifies its spectrum holdings for the provision of telecoms services.

Resell or redistribution of spectrum is not permitted

A licensee is not allowed to resell or redistribute spectrum to other parties. Licensees shall only transmit using their own assigned spectrum as specified in their respective licences, and the radio signal should be identifiable as the signal of that licensee. However, a licensee may lease its network capacity to another operator for its use, including using the capacity for implementation of carrier aggregation.

Extent of technology and service-neutral spectrum

Spectrum for public mobile telecoms services is in general assigned as technology neutral.[38] Under the technology-neutral principle, any operator is free to choose whatever transmission technology and standard it wishes for the provision of telecoms services, if it complies with the requirements of

---

37 Source: Cap. 106 Telecommunications Ordinance, Part 5B Management of Radio Spectrum and Prevention of Interference, Section 32H (5). Hong Kong

38 The only exception to the technology-neutral approach is the Mobile Carrier Licence No.099 held by HKT. Schedule 3 to the licence specifies the technical standard as "CDMA 2000 family of standards adopted by the 3GPP2, or other standard as approved by the CA".

all relevant legislations and its licence conditions. The technology and technical standard to be adopted for each spectrum band will therefore be based on a commercial decision made by each MNO. Spectrum can also be re-farmed without the need for approval from the CA.

In some cases, winning bidders at auctions can choose between fixed and/or mobile service(s) (specified in the auction's Information Memorandum). Once the selection is made and conditions are specified on the licence the operator holds, the operator must seek permission from the CA for a change of service.

Spectrum assignment term and re-assignment

Mobile spectrum assignments typically have a 15-year term, which tallies with the tenure of the UCL. According to the Radio Spectrum Policy Framework, there is no legitimate expectation that there will be any right of renewal or right of first refusal of any licence or spectrum assignment upon the expiry of a licence or spectrum assignment. At the end of the spectrum assignment period, the CA may align the frequency bands available for assignment with reference to the latest technological and market developments, to promote the efficient allocation and use of spectrum. Should the CA need to vary the assignment terms or withdraw a spectrum assignment, a minimum notice period of no less than three years would be given, insofar as it is practicable in the circumstances, if the spectrum is used by the operator of a network to establish a direct connection between the network and mobile subscribers. The CA is entitled to depart or deviate from the stated minimum notice period, if circumstances require it.

Public consultations are held to aid the CA on future decisions on the assignment/re-assignment of spectrum in accordance with the statutory requirements.

Spectrum available for assignment/re-assignment

As mentioned, spectrum is usually assigned for a 15-year period and spectrum in different frequency bands are assigned over different periods. Spectrum is therefore typically available for assignment/re-assignment through auction once every few years. As shown in Figure 3.1, there have been seven spectrum auctions for public mobile services since 2007, which means that there was about one auction every 1.4 year in the past decade. This creates opportunities, from time to time, for those players, including incumbent MNOs and new interested parties, who wish to acquire spectrum, to bid for the spectrum. This also creates opportunities, from time to time, for incumbent MNOs to review their overall spectrum holdings in deciding whether to take part in the competitive bidding of spectrum that takes place periodically, based on their then commercial considerations.

Spectrum caps and bidder association rules in auction

In the context of spectrum auctions, the CA may impose a cap on the amount of spectrum to be acquired by one bidder. This occurs if there is a competition concern arising from over-concentration of spectrum.

Spectrum caps are imposed in some auctions to restrict operators from holding too much spectrum:

- a 30MHz spectrum cap was in place in the auction for assignment of spectrum in the 2.3GHz band in 2012
- a 40MHz spectrum cap was in place in the auction for the re-assignment of spectrum in the 1.9–2.2GHz band in 2014
- a 90MHz spectrum cap will be in place in the auction for the re-assignment of spectrum in the 900MHz and 1800MHz bands (with a 20MHz sub-cap in the 900MHz band) to be held around the end of 2018.

Auction spectrum cap restrictions are considered in each assignment/re-assignment exercise on a case-by-case basis.

New entrants and established licensees may participate in spectrum auctions on their own or collaborate with others in the form of a joint venture (e.g. Genius Brand, a joint venture between Hutchison and HKT).

In the case of a spectrum cap restriction in an auction, there will be bidder association rules to restrict the participation of connected bidders. To be eligible as a qualified bidder, an entity must not have a connection to another bidder. In the context of a spectrum auction, a company has a connection to another bidder if it holds material interest (direct or indirect) in another company.

Roll-out obligations and performance bond

To prevent spectrum hoarding and/or under-utilisation, network and service roll-out obligations are imposed on spectrum assigned. These obligations may take the form of:

- a minimum number of commercial and/or residential buildings (where the scope of service in the licence includes fixed services) and/or
- coverage of the network and service provided to an area where at least a specified proportion of the population of Hong Kong live from time to time (where the scope of service in the licence includes mobile services).

A spectrum assignee is also required to submit a performance bond as a guarantee of its compliance with its respective network and service roll-out requirements.

Competition law

The CO, an ex-post cross-sectoral competition law, has been fully implemented in Hong Kong since December 2015. The CA has concurrent jurisdiction with the Competition Commission to enforce the CO in the telecoms and broadcasting sectors. Telecoms carrier licensees are subject to three competition rules:

- *"The first conduct rule provides that an undertaking must not make or give effect to an agreement, engage in a concerted practice, or as a member of an association of*

undertaking, make or give effect to a decision of the association, if the object or effect of the agreement, concerted practice or decision is to prevent, restrict or distort competition in Hong Kong;

- *The second conduct rule provides that an undertaking that has a substantial degree of market power must not abuse that power by engaging in conduct that has as its object or effect the prevention, restriction or distortion of competition in Hong Kong; and*

- *The merger rule provides that an undertaking must not, directly or indirectly, carry out a merger involving telecommunications carrier licensees that has, or is likely to have, the effect of substantially lessening competition in Hong Kong."*

There is no provision under the CO that explicitly prohibits the holding of excessive amounts of spectrum. Under the conduct rules, the fact that an MNO holds a relatively large amount of spectrum is not necessarily anti-competitive. Whilst the holding of an amount of spectrum relative to others can be a relevant consideration to assess the extent of market power held by an operator, the competition angle is ultimately on whether an operator's conduct concerning spectrum has an anti-competitive objective or effect. Under the merger rule, the extent of the concentration of spectrum because of a merger is generally a relevant consideration in assessing whether the merger may bring about a substantial decrease of competition in the relevant market.

Spectrum swap

General Condition 2.1 of the UCLs held by the MNOs provides that "*[t]he licensee may, only with the prior written consent of the [CA], and subject to such reasonable conditions as the [CA] thinks fit, transfer this licence or any permission, right or benefit under the licence*". Licensees may submit frequency swap requests (with no monetary exchange) to the CA for approval on a case-by-case basis.

When assessing a proposed swap, the CA bases its assessment on the following:

- **Monetary exchange**: No monetary exchange is permitted in proposed frequency swaps; additional consideration and safeguards may be put in place if the spectrum swap is seemingly asymmetrical (i.e. be more beneficial to one party than the other) and, if necessary, additional safeguards will be put in place by the CA to prevent hidden monetary exchanges in the proposed frequency swap.

- **Technical benefits**: The proposed swap will be reviewed favourably if it is demonstrated to have clear and tangible technical benefits (e.g. more flexible use of spectrum, reduction of radio interference, improvement in spectral efficiency, or the introduction of new or innovative services).

- **Licence obligations and commitments**: The proposed frequency swap should not affect underlying licence obligations and commitments applicable to the spectrum holder; it should also result in the transfer of licence obligations and conditions applicable to the concerned

spectrum between the parties, including the expiry date of the frequency assignments, payment of the spectrum utilisation fee (SUF) and licence fees, performance bonds and roll-out commitment.

- **Impact on customers**: The proposed swap should bring about benefits to customers (e.g. higher service speeds) and should not cause any enduringly adverse impacts on customers (such impacts could include interruption or lengthy degradation to services provided by the parties to customers, or to services provided by other MNOs to customers).

- **Consent of the parties**: The CA will only consider proposals where both parties have given their consent.

After taking the above list of factors into consideration, the CA has so far approved two requests for spectrum swaps between MNOs:

- between CMHK and SmarTone in the 1800MHz band (in 2012)
- between CMHK and HKT in the 2600MHz band (in 2016).

Mobile network sharing (including network capacity leasing)

In Hong Kong, MNOs have implemented certain types of mobile network sharing, such as antenna sharing, site sharing, radio access network (RAN) sharing and capacity leasing.

In the context of RAN sharing, MNOs may choose to have shared use of all or part of the RAN equipment and facilities including base stations, radio network controllers and backhaul transmission equipment. The shared RAN can be a single radio network which is connected to the core networks of different MNOs through the point of interconnection. For legitimate RAN-sharing scenarios in Hong Kong, each participating MNO will maintain its own separate logical RAN using its own assigned spectrum even if they share the use of the same RAN equipment and facilities with others. There should not be any pooling of spectrum by the participating spectrum assignees. The participating MNOs may also enter into operation and maintenance agreements under which the shared RAN will be managed and operated by one of the participating MNOs, or another third-party service provider.

Under the network capacity leasing arrangements, an MNO or mobile virtual network operator (MVNO) may lease the radio access capacity from other MNOs to expand its service coverage for an area or enhance its network capacity for its own subscribers. An MNO or MVNO may enter into a capacity leasing agreement with one or more MNO(s) to acquire a specified amount of mobile voice and data capacity from the RAN established by the latter party or parties.

With the advancement of carrier aggregation technology, an MNO may lease another MNO's radio access capacity and aggregate that capacity with its own to enable the provision of higher-speed mobile data services to its subscribers, provided that each MNO continues to operate its own separate logical RAN using its assigned spectrum i.e. the radio signal should be identifiable as the signal of that licensee. In this case, the physical RAN is shared between the lessor and lessee(s).

MNOs may negotiate and agree among themselves on mobile network sharing arrangements without intervention by the CA, if they are not in breach of the restrictions and obligations imposed by the law and by their carrier licences. There is currently no restriction on an MNO outsourcing the operation and management of its networks (including its core network and RAN) to other MNOs or other third-party service providers.

MVNOs licensed under Services-Based Operator (SBO) Class 3 (MVNO) licences are not permitted to operate their own mobile access and transmission networks, and therefore spectrum cannot be assigned to them. MVNOs are authorised to establish and maintain core networks, including but not limited to billing, switching, home location registers and Intelligent Network systems.

Withdrawal of spectrum assignments

The TO grants power to the CA to vary or withdraw frequencies assigned in exceptional circumstances. Section 32H (3) and (4) of the TO also provides that the CA may only exercise such power if it "*has given reasonable notice of the intended variation or withdrawal to the licensee which has been assigned the relevant frequency*".

There is a special condition under the UCL which states that the CA may withdraw any frequency previously assigned to the licensee in the following scenarios:

- The licensee is not making efficient use of the frequency
- There is a serious breach of licensing conditions
- There are serious interference issues between legitimate spectrum users that must be resolved or minimised
- Other exceptional circumstances (i.e. withdrawal of frequency is in the public interest or withdrawal is due to international obligations of the government).

The above withdrawal mechanism is also mentioned in the Radio Spectrum Policy Framework of 2007.

3.1.3 The Hong Kong spectrum management framework

Hong Kong's current spectrum management framework for public mobile telecoms services is reasonably effective in promoting the efficient use of spectrum. Market-based mechanisms have largely been adopted, with safeguards against hoarding, under-utilisation or anti-competitive behaviour. Spectrum is generally re-assigned upon expiry using the market-based approach, unless there are overriding public policy reasons to do otherwise. There are opportunities from time to time for parties, including established operators and new interested parties, who wish to acquire spectrum through participating in auctions held by the CA.

Operators also have flexibility to adapt to changes in technology and market conditions under the current regulatory regime, through technology-neutrality provisions in spectrum management, and availability of spectrum swaps. Various forms of mobile network sharing, including RAN sharing

and capacity leasing, also provide opportunity for operators to obtain additional network capacity as and when required, giving operators flexibility to adapt to changes in market demand. Additionally, an MNO (the lessor) that is leasing capacity to another party may also configure base stations to the extent that its tenant (or lessee) is the only operator using capacity from spectrum in a band. This potentially allows the tenant more control over where additional capacity is to be deployed.

We also note the ability of the CA to withdraw spectrum for re-assignment to higher-value uses. For example, the CA has recently exercised its power to withdraw spectrum in the 26GHz band from SmarTone and Hutchison to pave way for the development of 5G services in Hong Kong.

3.2 Industry views on spectrum transfer and trading

We conducted a series of interviews with selected industry representatives to collect views on a potential spectrum trading regime in Hong Kong. The interviews were structured to clarify the potential benefits and costs of spectrum trading to consumers, businesses and users of spectrum, through exploring challenges that different industry players had faced in deploying mobile services. We asked the interviewees to describe their plans to purchase or lease spectrum should spectrum trading be established in Hong Kong. Interviewees were also asked their views on the alternative mechanisms currently in place. The full list of questions and interviewees is provided in Annex E.

Most interviewees did not have a strong view for or against spectrum trading and indicated that they would require more details on the implementation and process before commenting further. However, there were operators with strong views on this topic. One operator heavily supported the introduction of a spectrum trading regime. Other operators were less enthusiastic, stating fears of increased risks due to anti-competitive activities. A summary of their key comments is represented below. The detailed responses of the industry representatives are provided in Annex F.

Potential benefits of spectrum trading

Operators believed that spectrum trading could improve the efficiency of spectrum usage under certain circumstances. Operators also felt that spectrum trading could facilitate the divestment of non-strategic spectrum assets, rebalance MNO spectrum portfolios and increase flexibility in spectrum management.

Potential costs of spectrum trading

Operators suggested costs/risks like those raised in Section 2.3, with spectrum speculation being the most troubling for four out of the seven MNOs/MVNOs interviewed. Interviewees also highlighted the over-concentration of spectrum and potential of windfall profit as concerns.

Implementation costs were also brought up by more than half of the interviewees, including the difficulties in implementing a spectrum trading framework, and complications related to managing spectrum that is already in the market.

Likelihood of participation	All operators interviewed have no concrete plans to participate in spectrum trading at present. They mentioned that they would require more details on the proposed regime before they can make further decisions. One operator was very enthusiastic about the idea of a spectrum trading regime, whereas another expressed strong reservations on the matter.
Alternative mechanisms – spectrum swaps	Interviewees had different opinions on the efficacy of the current mechanisms for spectrum swaps. One felt that spectrum swaps were successful to a certain degree, while others felt that there could be room for greater flexibility via a spectrum trading regime. Five operators also noted that, unlike spectrum trading, the spectrum swap process does not provide an opportunity for monetary gains.
Alternative mechanisms – network capacity leasing	Interviewees also held differing stances on the efficacy of the current network capacity leasing mechanisms. Two operators were of the view that the MVNO mechanism is a good alternative to spectrum trading, as it allows new entrants to provide mobile services without having to invest heavily in infrastructure. On the other hand, two other operators noted that a shortfall of this mechanism is that MVNOs lack control over network deployment.
Possibility of no trading	Feedback from operators was that the possibility of no spectrum trading would not impact their current operations, as they did not consider the possibility of trading when they initially bid for the spectrum.

3.3 Assessment of market situation

In this section, we provide an assessment of the Hong Kong market situation. We evaluate the competitiveness of the market, the potential for new entrants and the current demand for and supply of mobile spectrum.

This section also provides an assessment of the current Hong Kong spectrum management framework in terms of its ability to effectively manage the utilisation of spectrum. The level of current spectrum efficiencies will influence the future impact of potential spectrum trading in Hong Kong, and therefore a band-by-band analysis of mobile spectrum bands will be provided, to assess the overall potential for spectrum trading within the bands assigned for mobile use in Hong Kong.

3.3.1 Market structure and contestability

Hong Kong has a highly penetrated mobile market with a total of 18.3 million subscribers and a mobile subscriber penetration rate of 248% as at December 2017. There are four MNOs in the market, CMHK, SmarTone, HKT and Hutchison, after a consolidation of players in 2014, when HKT acquired CSL.

Post the HKT–CSL merger, subscriber market share had shifted slightly, with CMHK and SmarTone gaining some market share from the merged HKT–CSL entity between 2014–2015. This can be attributed to the aggressive marketing campaigns from CMHK and SmarTone. As of 2016, the subscriber market share had largely stabilised.[39]

As of January 2018, there were 29 licensed MVNOs in the Hong Kong market, including established MVNOs such as Sun Mobile, China Unicom and NTT Com Asia, and new entrant Hong Kong Broadband Network (HKBN). HKBN entered the market in September 2016 with SmarTone and CMHK as its hosting MNOs. It has been particularly aggressive in its acquisition of subscribers by leveraging on its existing fixed network to offer bundled promotions and reduced prices.

The MVNO mechanism is one of the channels for entering the Hong Kong mobile market. The upcoming re-assignment of 900/1800MHz spectrum upon expiry of existing assignments in 2021 (with the auction to be held in end 2018) also provides an opportunity for new entrants into the Hong Kong mobile market.

Overall, there is a keenly competitive market for mobile services in Hong Kong, which is clearly reflected in the competitive marketing and pricing strategies of both MNOs and MVNOs.

3.3.2 Demand and supply for mobile spectrum

Demand for mobile spectrum

In Hong Kong, industry players' demand for additional spectrum is high. In interviews with industry stakeholders, all the interviewed MNOs expressed a need for the CA to release more spectrum to support increasing demand for mobile data services and to prepare for the launch of 5G services.[40]

It is likely that the industry will have a sustained demand for mobile spectrum (especially in sub-3GHz spectrum bands).

Supply of mobile spectrum

Currently, 582MHz of spectrum in the sub-3GHz frequency bands has been released by the CA for public telecoms services:

- 552MHz of spectrum for mobile services
- 30MHz of spectrum for fixed wireless services.

39 Source: GSMA Intelligence, 2017.

40 The launch of 5G services is anticipated to occur in approximately 2020.

When assessed on a band-by-band basis, most common sub-3GHz spectrum bands identified by the ITU for International Mobile Telecommunication (IMT) has already been released in Hong Kong, except for the 2.6GHz (2570–2620MHz) TDD band and the 700MHz band (698–806MHz).

We note that spectrum in the 2.6GHz TDD unpaired spectrum band has not been released by all key international counterparts that have released 2.6GHz spectrum as paired bands (2500–2570MHz, 2620–2690MHz). At the end of June 2017, the Global Mobile Suppliers Association noted that out of 98 commercial networks that have launched TDD-LTE, only 19 networks used 2.6GHz TDD bands.[41] In Hong Kong, the 2600–2615MHz frequency band was listed as part of the spectrum auction for broadband wireless access services in 2009 but was not acquired by any bidder.

The 700MHz band currently remains allocated to terrestrial TV broadcasting services in Hong Kong. Many markets have sought to derive a 'digital dividend'[42] as digital terrestrial TV (DTT) services, which replaces analogue broadcast, typically requires less spectrum. This 'dividend' has taken the form of spectrum in the 600MHz, 700MHz or 800MHz bands being released for other uses, chiefly public mobile services. This requires a high degree of cross-border co-ordination, since broadcast networks typically emit at a high-power level that can cause interference across borders. In Hong Kong, any change to service allocation in the 700MHz band requires frequency co-ordination with Mainland China authorities. We note that the CA has announced its intention to allocate part of the 700MHz band to mobile services subject to successful frequency co-ordination.

As can be seen from the above discussion, it is therefore not clear whether there will be any new supply of spectrum in frequency bands below 3GHz in Hong Kong soon.

In March 2017, the CA announced an intention to make available additional spectrum in frequency bands above 3GHz for public mobile services from 2019. This would cover spectrum in the 3.4–3.6GHz band ('the 3.5GHz band'), the 24.25–27.5GHz band ('the 26GHz band') and the 27.5–28.35GHz band ('the 28GHz band').

In many jurisdictions, the 3.5GHz band[43] has been considered for 5G implementation. In Hong Kong, the 3.5GHz band is allocated to the fixed satellite service. Shared use of this band will result in interference concerns as signals from base stations and handsets are strong compared with signals from the satellite. A (partial) vacation of the fixed satellite service will be required before the 3.5GHz band can be re-allocated to public mobile services. After public consultation, the CA decided in March 2018 to change the allocation of the 3.5GHz band from fixed satellite service to public mobile

41 Source: Evolution from LTE to 5G, Global Mobile Suppliers Association, July 2017.

42 Digital dividend is defined as the amount of spectrum in the VHF and UHF bands that is above what is nominally required to accommodate existing analogue programmes, and that might be thus potentially freed up in the switchover from analogue to digital television.

43 Comprising 200MHz of spectrum between 3.4GHz to 3.6GHz, plus a further 200MHz of spectrum from 3.6–3.8GHz, providing, in some markets, a total of 400MHz of spectrum between 3.4 and 3.8GHz.

services with effect from April 2020. [44] A further consultation on the assignment arrangements of spectrum in this band and related SUF is underway.[45]

The 26GHz and 28GHz bands offer, in combination, a contiguous bandwidth of 4.1GHz. According to the CA's work plan announced in March 2017, these bands will be made available as the first batch of new spectrum for the provision of 5G services in Hong Kong. At present, the 27–31GHz band, which overlaps partially with the 26GHz band and entirely with the 28GHz band, is allocated to fixed satellite service, but it has not been deployed for services yet. The satellite industry has commented that this band is important for the future development of satellite services. Part of the 26GHz band is being assigned and used for terrestrial fixed links and the CA served notices to the spectrum assignees in April 2017 on the withdrawal of the assigned spectrum, which will take effect from 1 April 2019. In December 2017, the CA invited the industry players to express their interest in using the 26GHz and 28GHz bands for 5G services. Subject to the CA's decision after public consultation, spectrum in the 26GHz and 28GHz bands can be assigned for the provision of public mobile services in 2019 at the earliest. Hong Kong will be one of the few markets planning to release both the 26GHz and 28GHz bands for 5G services at such an early time.

The availability of commonly used mobile spectrum and current spectrum holdings in selected developed markets is shown in Figure 3.2 below.

44 The CA Statement on "Change in the Allocation in the 3.4-3.7 GHz Band from Fixed Satellite Service to Mobile Service" issued on 28 March 2018 is available at: https://www.coms-auth.hk/filemanager/statement/en/upload/441/ca_statements20180328_en.pdf.

45 The consultation paper on "Arrangements for Assignment of the Spectrum in the 3.4 – 3.6 GHz Band for the Provision of Public Mobile Services and the Related Spectrum Utilisation Fee" issued on 2 May 2018 is available at: http://www.cedb.gov.hk/ccib/eng/paper/pdf/3.5GHz_Spectrum_consultation.pdf

Figure 3.2: International benchmark of commonly used mobile spectrum released by selected NRAs worldwide [Source: Various NRAs, 2018]

	700MHz	850/900MHz	1800MHz	1.9–2.2GHz	2.3GHz	2.5–2.6GHz FDD	2.6GHz TDD	3.4–3.8GHz	26GHz	28GHz	Current spectrum holdings (MHz)
Hong Kong		✓	✓	✓	✓	✓		Δ	Δ	Δ	582
Australia	✓	✓	✓	✓	✓	✓		Δ	Δ		688
Canada	✓	✓	✓	✓	✓	✓	✓			Δ	648
Mainland China[46]		✓	✓	✓	✓	-	✓	Δ	Δ		522
Japan[47]	✓	✓	✓	✓		-	✓	✓/ Δ		Δ	641
New Zealand	✓	✓	✓	✓	✓	✓	✓	Δ	Δ		680
Singapore	✓	✓	✓	✓	✓	✓	✓		Δ	Δ	640
Switzerland	Δ	✓	✓	✓		✓	✓	Δ			573
UK[48]	Δ	✓	✓	✓	Δ	✓	✓	✓/ Δ	Δ		647
USA[49]	✓	✓	✓	✓	✓	✓		Δ	✓	✓	2266 (sub-3GHz: 716)

Legend: ✓ – spectrum already assigned for mobile telecoms use; Δ – re-assignment/preparation towards new assignment in progress

46 The entire 190MHz in the 2600MHz spectrum band is allocated for TDD service provision. Source: https://www.telecomasia.net/content/lte-spectrum-scenarios-china.

47 2×35MHz of spectrum in the 1500MHz band and spectrum from 3480MHz to 3600MHz has also been assigned for mobile communications services in Japan. The Japanese NRA has assigned the 2.5–2.6GHz band to AXGP standard, which is TDD compliant. Source: https://www.telegeography.com/products/commsupdate/articles/2013/06/26/mic-announces-public-consultation-on-the-use-of-2-5ghz-band-for-bwa/.

48 L-Band spectrum (1452MHz to 1492MHz) and 40MHz of spectrum in the 3.4GHz band have also been assigned for wireless broadband services in the UK. Assignment of the remaining spectrum in the 3.4GHz band is in progress.

49 The USA recently assigned up to 70MHz of spectrum in the 600MHz band for mobile and other wireless broadband services. Spectrum from 24.25–24.45GHz and 24.75–25.25GHz have also been assigned for mobile telecoms use. Source: Use of Spectrum Bands Above 24GHz for Mobile Radio Services, Second Report and Order, Second Further Notice of Proposed Rulemaking, Order on Reconsideration, and Memorandum Opinion and Order, Federal Communications Commission, Oct 2017.

It is likely that, in the short term, the supply of sub-3GHz spectrum is expected to remain constrained in the Hong Kong market when compared to demand for this spectrum. We note, however, that there will be a supply of additional mobile spectrum in frequency bands above 3GHz from 2019.

3.3.3 Utilisation of mobile spectrum in Hong Kong

In general, sub-3GHz spectrum is well utilised in the Hong Kong market. This is likely due to the incessant demand for mobile data services in Hong Kong. MNOs therefore have greater impetus to fully utilise their available spectrum to support network capacity requirements from their subscribers.

To study the general utilisation of mobile spectrum in Hong Kong, we have assessed the spectrum assigned on a band-by-band basis (see Figure 3.3). This includes a summary of each MNO's current spectrum holdings in the mobile spectrum bands. Hong Kong's full mobile spectrum map is provided in Annex G.

Figure 3.3: Band-by-band assessment of mobile spectrum in Hong Kong [Source: Analysys Mason, 2018]

Frequency band	Year of assignment (expiry)	Spectrum holders (bandwidth assigned)	Current use	Remarks
850MHz	2008 (2023)	HKT (2×7.5MHz)	CDMA2000	• This spectrum was assigned on the condition that CDMA2000 technology would be deployed, in accordance with the government's overriding policy objective to strengthen Hong Kong's strategic position as a world city and the gateway to Mainland China
850/900MHz	2011 (2026)	SmarTone (2×5MHz) Hutchison (2×5MHz)	3G	• Spectrum assigned as technology neutral • Auctioned along with unpaired 2GHz spectrum (2010.0–2014.8MHz; 2014.8–2019.7MHz) which did not receive interest from MNOs; spectrum is currently being kept in reserve
900MHz	2005/2006 (2021)	HKT (2×8.3MHz) Hutchison (2×8.3MHz) SmarTone (2×8.3MHz)	2G and 4G	• Spectrum assigned as technology neutral • At the time of assignment, spectrum in the 900MHz and 1800MHz band was used for the provision of 2G services; frequency blocks are in multiples of 2×0.2MHz, which is the bandwidth of a carrier for 2G services • Operators have re-farmed a portion of spectrum in these bands for LTE • The CA has decided to re-align the spectrum blocks to resolve issues regarding fragmentation of spectrum holdings in the next term of assignment commencing 2021; an auction is expected around the end of 2018 • Frequency swap between SmarTone and CMHK in the 1800MHz band to increase efficiency of spectrum
1800MHz	2006/2009 (2021)	HKT (2×36.4MHz) Hutchison (2×11.6MHz) SmarTone (2×13.2MHz) CMHK (2×13.2MHz)	2G and 4G	
1.9–2.2GHz	2016	HKT	3G and 4G	• Spectrum assigned as technology neutral

Frequency band	Year of assignment (expiry)	Spectrum holders (bandwidth assigned)	Current use	Remarks
	(2031)	(2×14.8MHz) Hutchison (2×14.8MHz) SmarTone (2×19.8MHz) CMHK (2×14.8MHz)		• If there is a possibility to structure the spectrum assignment as 2×20MHz, a more efficient spectrum utilisation may be achieved; however, this would depend on the willingness of operators to swap their current spectrum holdings
2.3GHz	2012 (2027)	Hutchison (30MHz) CMHK (30MHz) 21 ViaNet (30MHz)	4G (Hutchison, CMHK) Fixed wireless (21 ViaNet)	• Spectrum assigned as technology neutral • Spectrum block size of 30MHz may not be conducive to deploying spectrum in the most technically efficient manner for LTE deployment, as spectrum is technically most efficiently deployed in blocks of 20MHz; however, this would depend on the willingness of operators to swap their current spectrum holdings
2.5-2.6GHz[50]	2009 (2024)	Genius Brand (2×15MHz) CMHK (2×20MHz) HKT (2×10MHz)	4G	• Spectrum assigned as technology neutral • 105MHz of spectrum in the 2500–2690MHz band was made available for assignment, including 90MHz of paired spectrum and 15MHz of unpaired spectrum; the unpaired spectrum was not acquired by any bidder in the auction • Frequency swap between HKT and CMHK to increase efficiency of spectrum use for LTE

50 Involves spectrum in band 2500–2515, 2540–2570, 2620–2635, 2660–2690MHz.

Frequency band	Year of assignment (expiry)	Spectrum holders (bandwidth assigned)	Current use	Remarks
2.5–2.6GHz[51]	2013 (2028)	Genius Brand (2×5MHz) SmarTone (2×10MHz) HKT (2×10MHz)	4G	

51 Involves spectrum in band 2515–2540 and 2635–2660MHz.

As shown in Figure 3.3, spectrum in Hong Kong is generally well utilised. There are some short-term inefficiencies (i.e. fragmentation of holdings at 900/1800MHz bands) that will be improved through the re-assignment of spectrum in 2021. This reduces the overall urgency to introduce spectrum trading.

3.3.4 Overall demand for and supply of spectrum trading

Potential demand for spectrum trading

As described in Section 3.3.2, industry players' demand for mobile spectrum is high. Operators looking to increase their network capacity in face of the challenge of 4G data growth, could potentially acquire more spectrum through the secondary market, if such a supply is available. It can be expected that some of industry's demand for spectrum may translate to potential demand for spectrum trading.

We note that the overall demand for spectrum trading will be impacted by the rules on trading eligibility. If trading is only limited to MNOs, demand for trading will inevitably be affected as the number of potential buyers for the spectrum decreases. On the other hand, allowing all interested parties (e.g. including newcomers) to trade will likely result in an increase in the overall demand for spectrum trading.

Demand for spectrum trading may also be affected by the on-going spectrum auctions to be conducted by OFCA, and the planned future release of new spectrum for mobile services. The latter is being proactively addressed by the CA, particularly in frequency bands above 3GHz, at this very moment in preparation for commercial launch of 5G from 2019/2020 onwards. MNOs or other interested parties may choose to wait for the availability of new spectrum, and acquire it for a full 15 years' term, rather than entering into negotiations with the incumbent/established players to trade spectrum for the remaining duration of the assignment period and generating transaction costs. The process of negotiation takes time and its outcome may be uncertain.

Potential supply of spectrum trading

In Hong Kong the supply of available mobile spectrum will affect the supply of spectrum in the secondary market. In cases where the supply of available spectrum is likely to be abundant in future, it is likely that more operators can afford to sell their spectrum without significantly impacting their network quality. However, the supply of available spectrum in the sub-3GHz bands in the primary market will remain constrained in Hong Kong in the short term. MNO demand for additional spectrum will also remain high. It is therefore unlikely that spectrum holders would be willing to sell their spectrum resources in the secondary market.

The supply of trading may also be influenced by changes in market share, notably in situations when an overall decrease in market share results in the under-utilisation of spectrum. As the opportunity cost of holding additional spectrum becomes more obvious in markets with spectrum trading,

operators may be willing to give up their underutilised spectrum to the secondary market for monetary compensation, instead of letting the resource remain idle.

However, current spectrum utilisation in Hong Kong is generally high and the market shares of MNOs remain relatively stable. There is no indication of significant changes in market share that will result in an operator having significantly less usage requirements. The potential supply of spectrum into the secondary market therefore remains questionable, if spectrum trading were permitted.

Other comments on potential participation in spectrum trading

The MNOs and MVNOs that were interviewed did not express clear intentions to buy or sell spectrum in the secondary market. Most noted that their decision would be driven by their individual business case. Their decisions would also be dependent on the rules and regulations of the overall Hong Kong spectrum trading regime, when implemented. Given this non-committal approach by the interviewed operators, it is challenging to quantitatively assess the potential demand and supply of spectrum trading in Hong Kong. It should be noted, however, that only one interviewed operator strongly supported the introduction of spectrum trading in Hong Kong.

4 Benefits and costs of introducing a spectrum trading regime in Hong Kong

In this section, we assess the impact of introducing a spectrum trading regime in Hong Kong, through an analysis of the relevant benefits and costs/risks of spectrum trading. In conducting the assessment, we have considered the existing spectrum management framework in Hong Kong alongside future roadmaps.

4.1 Assessing the relevance of spectrum trading in Hong Kong

As set out in Section 2 of this report, spectrum trading generally facilitates more flexible market-based spectrum exchanges. However, the associated benefits of spectrum trading are balanced by its potential costs/risks. The question of whether the current spectrum management framework in a market could yield similar benefits should also be investigated.

The impact of a spectrum trading regime is largely market-specific, and not all the benefits and costs/risks mentioned in Section 2 will have the same relevance and impact in Hong Kong. Below we apply market and regulatory factors extracted from Section 3.1 to better understand the benefits and costs/risks that are applicable in the Hong Kong context.

- *Potential benefits*

Hong Kong does not have regional licensing or perpetual licensing terms. Certain spectrum trading benefits will therefore not be applicable in Hong Kong, for example being able to aggregate regional spectrum holdings and/or being able to adapt spectrum use in the presence of perpetual licensing. Several industry interviewees agreed with this perspective – they saw little relevance for some of these benefits in the Hong Kong context.

Figure 4.1 provides a summary of benefits derived from international spectrum trading examples and notes the relevance of these benefits to potential spectrum trading in a Hong Kong context.

Figure 4.1: Relevance of benefits of spectrum trading in a Hong Kong context [Source: Analysys Mason]

Potential benefit of spectrum trading	Relevance to Hong Kong
Aggregation of regional spectrum holdings	✗
Rejuvenation of underutilised spectrum	✓
Lowering barriers to expansion	✓
Flexibility to allow spectrum use to evolve with changing market demands	✓
Additional incentives to change the use of spectrum in regimes with long or perpetual licences	✗
Reduction of administrative burden on the regulator under specific regulatory context	✗

► *Potential costs/risks*

Feedback from several industry stakeholders suggests that costs related to spectrum hoarding and over-concentration should be a cause for concern. Industry stakeholders also mentioned the potential difficulties in the treatment of windfall profits/losses from spectrum already in the market.

The concerns highlighted by the industry can be regarded as key considerations when assessing the merits of introducing a spectrum trading regime. In our subsequent analysis, we focused on the opportunity for spectrum hoarding, profits (including but not limited to windfall profits) and over-concentration of spectrum, as well as the available safeguards against these concerns.

Although potential costs because of loss of harmonisation, and increased risk of interference were not highlighted in the industry interviews, they are nonetheless important from a regulatory perspective. There may be amendments required to adapt existing safeguards to a formal spectrum trading regime, and further assessment is therefore warranted.

Figure 4.2 provides a summary of costs derived from international spectrum trading examples and notes the relevance of these costs to potential spectrum trading in a Hong Kong context.

Figure 4.2: Relevance of costs of spectrum trading in a Hong Kong context [Source: Analysys Mason]

Potential costs/risks of spectrum trading	Relevance to Hong Kong
Spectrum hoarding	✓
Windfall profits or other private profits gained by trading parties	✓
Over-concentration of spectrum leading to foreclosure of competition	✓
Loss of harmonisation	✓
Increased risk of interference	✓
Distortion of auction dynamics	✓

► *Time dimension for assessment*

Benefits of spectrum trading will be more pronounced when

- there are clearly identified inefficiencies in the market that are unlikely to be addressed through re-assignment of spectrum upon expiry of assignment period
- these inefficiencies strongly call for spectrum trading as a resolution.

However, if current spectrum utilisation in the market is already sufficiently efficient, the urgency to implement spectrum trading is reduced. In addition, it should be noted that it takes time and effort to set up a spectrum trading regime (e.g. Ofcom in the UK took six years). It may therefore not be the relevant solution to address short-term needs.

Even if there is little urgency to introduce spectrum trading in the short term, introducing spectrum trading in the medium term should still be evaluated as a potential mechanism to enhance the overall spectrum management regime.

We have conducted our subsequent analysis based on the following time periods:

- **Short term** (in the next five years): Key spectrum management topics are the continuous evolution of 4G spectrum access, the early release of suitable spectrum for 5G deployment, and the gradual decommissioning of 2G and 3G services.
- **Medium term** (in the next five to ten years): Key spectrum management topics are facilitating the market for the further development and deployment of 5G technologies under different scenarios and use cases, as the technology evolves.

4.2 Short-term assessment of the introduction of a spectrum trading regime

Based on the current technology roadmap, some developed markets have begun to switch off their 2G networks (despite having active 2G subscribers) and migrating users to 3G and 4G services. These markets include Australia, Singapore, Japan and South Korea. Hong Kong operators may follow suit soon. Any short-term assessment will have to keep in mind the possible decommissioning of 2G and the re-farming of spectrum that was previously deployed for 2G services for 4G use. As of December 2017, Hong Kong had 1.4 million 2G subscribers[52] (~7.9% of the total number of mobile subscribers).

Operators in developed markets have also started to consider the transition from 3G to 4G technologies (including LTE-A, and its derivatives, such as Narrow-Band IoT and other application-specific uses) within the next five years to cope with the growing consumer demand for data. 4G is more optimised for data than 3G technologies, and allows for enhanced speed and capacity for the same amount of spectrum deployed. Our short-term assessment therefore also considers the possible decommissioning of 3G services.

4.2.1 Current spectrum holdings overview

An overview of current spectrum holdings in Hong Kong is shown in Figure 4.3. This provides context for the further assessment of the potential impacts of a spectrum trading regime and the likelihood of these impacts.

52 Source: Key statistics for telecommunications in Hong Kong Wireless Services, OFCA, Feb 2018.

Figure 4.3: Spectrum holdings by operator in Hong Kong [Source: OFCA, 2018]

Spectrum	850/900MHz	900MHz	1800MHz	1.9–2.2GHz	2.3GHz	2.5–2.6GHz	Total spectrum holdings
Usage	*3G*	*2G and 4G*	*2G and 4G*	*3G and 4G*	*4G/fixed*	*4G*	
HKT	2×7.5MHz[53]	2×8.3MHz	2×36.4MHz	2×14.8MHz		2×20MHz	174MHz
SmarTone	2×5MHz	2×8.3MHz	2×13.2MHz	2×19.8MHz		2×10MHz	112.6MHz
Hutchison	2×5MHz	2×8.3MHz	2×11.6MHz	2×14.8MHz	30MHz		109.4MHz
CMHK			2×13.2MHz	2×9.8MHz	30MHz	2×20MHz	116MHz
21 ViaNet					30MHz		30MHz
Genius Brand						2×20MHz[54]	40MHz

53 HKT's 2×7.5MHz spectrum in the 850MHz band is the only spectrum assignment that is not technology-neutral, restricted only for CDMA2000 technology.

54 Genius Brand is a joint venture between HKT and Hutchison. Both HKT and Hutchison will be able to rely on Genius Brand for 4G network capacity.

As shown in Figure 4.3, multiple spectrum bands are used in Hong Kong for a combination of 2G/3G and 4G deployment. As spectrum is in general technology neutral, MNOs can re-farm spectrum to adapt to changing technology and market conditions. Some spectrum in the 900MHz and 1800MHz bands has already been re-farmed to support 4G services.

Overall, in relation to its rival carriers, each operator has at least three to four spectrum bands that can be utilised to address demands from 4G. This pattern of spectrum holdings is also common to other markets.

4.2.2 Assessment of the potential benefits of a spectrum trading regime in Hong Kong

Our assessment of the potential benefits that spectrum trading can bring to operators and consumers in Hong Kong within the next five years is shown in Figure 4.4. Our assessment has considered the market and technology changes that can be anticipated in this timeframe.

Figure 4.4: Assessment of the benefits of introducing spectrum trading to Hong Kong in the short term [Source: Analysys Mason, 2018]

Benefit	Relevance to Hong Kong	Current situation in Hong Kong
Aggregation of regional spectrum holdings	• Not relevant to Hong Kong	• Hong Kong does not have a regional licensing regime
Rejuvenation of underutilised spectrum	• Spectrum trading can facilitate better flexibility to reorganise spectrum holdings to attain greater deployment efficiency, based on the latest technology development and evolution	• High utilisation of released mobile spectrum in Hong Kong, therefore the likelihood of trading is highly dependent on operator's willingness to trade • There is also an opportunity to re-organise spectrum assignment when existing spectrum assignments expire
Lowering barriers to expansion	• Spectrum trading will provide an additional avenue for existing players to gain spectrum for further expansion as and when required and for new entrants to enter the Hong Kong telecoms market	• Currently, this is facilitated through participation in auctions (which will occur from time to time for assignment/re-assignment of spectrum) and the M&A of existing players • As the telecoms market in Hong Kong is highly competitive, spectrum is generally well utilised, and even though the current demand for spectrum is greater than the supply, we do not anticipate that existing MNOs will sell their spectrum in the secondary market in the short term • MNOs may reach commercial arrangements with other MNOs for mobile network sharing including RAN sharing and capacity leasing to supplement their existing radio access

Benefit	Relevance to Hong Kong	Current situation in Hong Kong
		capacity to respond to changes in market demand
Flexibility to allow spectrum use to evolve with changing market demands	• Evolution of technology standards may require spectrum trading to facilitate the reorganisation of spectrum configuration in existing bands to allow spectrum to be deployed in a more technically efficient manner	• Unlikely to impact spectrum assignment in the Hong Kong market in the short term, as 4G technology is already mature • Hong Kong has generally adopted a technology-neutral approach to spectrum assignments. Operators can use any technologies as required. We note that Hong Kong is one of the markets with the earliest launch of 4G services • Operators can also acquire spectrum for system expansion/optimisation through auctions conducted for re-assignment of spectrum upon expiry
	• Spectrum trading could potentially help rebalance spectrum holdings if there is a significant change in market share that leads to a drastic change in spectrum demand	• As spectrum will be re-auctioned after expiry of its 15-year assignment, operators may review the spectrum holdings and decide whether to participate in the subsequent auction • MNOs may reach commercial arrangements with other MNOs for mobile network sharing to supplement their existing radio access capacity to respond to changes in market demand • Even if a spectrum trading regime is in place, whether such trade would materialise is questionable, as spectrum in Hong Kong is generally well utilised
Additional incentives to change the use of spectrum in regimes with long or perpetual licences	• Not relevant to Hong Kong	• Hong Kong does not have a long or perpetual licensing regime
Reduction of administrative burden on the regulator under specific regulatory context	• Not relevant to Hong Kong	• Hong Kong does not have regional licensing regime, which may lead to a high volume of transactions requiring administrative processing • Benefits from reduction in administrative burden is unlikely to materialise, as low volume spectrum trading is expected in Hong Kong

Some of the benefits of a spectrum trading regime, including additional timing flexibility and flexibility as to the types of transactions (both symmetric or asymmetric) permitted, can also be conferred in a regime without spectrum trading.

4.2.3 Assessment of the potential costs of a spectrum trading regime in Hong Kong

Our assessment of the potential costs/risks that the introduction of spectrum trading may bring to operators, the general public and the Government of Hong Kong in the next five years is shown in Figure 4.5.

Figure 4.5: Assessment of potential costs of introducing spectrum trading to Hong Kong in the short term [Source: Analysys Mason, 2018]

Issues	Potential cost to Hong Kong	Available safeguards and difficulties of implementing these safeguards
Spectrum hoarding	• The propensity of speculative and anti-competitive hoarding increases if spectrum trading is introduced, which could lead to under-utilisation of existing spectrum to the detriment of operators and other stakeholders in Hong Kong • Speculative hoarding decreases the spectrum available for use in the market; anti-competitive hoarding may foreclose other competitive operators from the market	• Roll-out obligations is already in place in Hong Kong. While imposing more roll-out obligations can be considered, this may decrease flexibility for operators genuinely engaged in network deployment • Anti-competitive behaviour could be dealt with under the CO. The question of whether holding excessive spectrum could be regarded as anti-competitive conduct would need to be analysed on a case-by-case basis and would need to consider the prevailing market circumstances
Windfall profits and other private profits gained by trading parties	• Private profits could lead to concerns regarding the fairness of benefit distribution between the government and spectrum users	• Hong Kong does not currently appear to have mechanisms to safeguard against windfall gains and other profiteering opportunities • Implementation of additional tax or additional spectrum fees can be considered, but might not be adequate to mitigate all profiteering opportunities • Public perceptions on private profits remain difficult to manage, and there will be additional complexities placed on the ex-ante trading review process to mitigate the risk of unfair profiteering
Over-concentration of spectrum leading to foreclosure of competition	• Spectrum trading will make it easier for certain existing MNOs to acquire spectrum, potentially preventing competitors from	• Anti-competitive conduct could be dealt with under the CO. The question of whether holding excessive spectrum could be regarded as anti-competitive conduct would need to be analysed on a case-by-case basis and would need to consider the prevailing market circumstances

Issues	Potential cost to Hong Kong	Available safeguards and difficulties of implementing these safeguards
	gaining access to spectrum • Such a scenario would have an impact on competition in the Hong Kong market by creating barriers for new entrants and/or restricting the expansion of rivals	• There is currently no spectrum cap across all bands. It may be necessary to consider its introduction or develop another safeguard against this risk
Loss of harmonisation	• Unlikely to be relevant if change-of-use trading is not allowed, as harmonisation is considered at the primary assignment • However, change-of-use trading, if allowed, would increase the potential loss of harmonisation	• Safeguards for loss of harmonisation are already in place, but if change-of-use is permitted, ex-ante regulatory scrutiny (similar to the approval for change of licensing conditions) has to be enacted to minimise potential loss of harmonisation
Increased risk of interference	• Spectrum trading will potentially increase the risk of interference due to additional spectrum usage scenarios enabled by spectrum trading	• Most spectrum licences define technical conditions to control the risk of interference, thus minimal impact is expected from the introduction of a spectrum trading regime, but extra assessment may be needed to review existing guidelines on interference
Distortion of auction dynamics	• Spectrum trading may affect prices paid at spectrum auctions in both directions • An upwards pressure on auction prices may result if bidders participate in auctions with the intention to acquire spectrum for future profiteering opportunities in addition to that for their own use • Lower prices are expected when there is an avenue for operators to purchase spectrum in the secondary market	• Quantitative analysis indicates that the introduction of spectrum trading has a minimal effect on revenue from primary awards (see Annex D) • Safeguards (e.g. roll-out obligations and service continuity regulations) are already in place, but allowing spectrum trading may make the implementation of safeguards slightly more complicated

4.2.4 Short-term assessment – conclusion

In the short term, a decision on the introduction of spectrum trading in Hong Kong appears to be a balance between (a) introducing more flexibility to the overall spectrum assignment regime in terms of permitting asymmetric trades (including partial trades of spectrum holdings) and increased time

flexibility in determining when spectrum can be acquired or relinquished, (b) managing costs and potential risks associated with spectrum trading, and (c) implementing safeguards and further regulatory controls required to forestall/alleviate such costs and risks and the related implementation costs.

At present, our research suggests there are no critical bottlenecks in the Hong Kong market that require spectrum trading as the only resolution. While the secondary market presents a means to re-assign spectrum to the most efficient use, the amount of trading activity is anticipated to be low, if any, given international examples of spectrum trading markets and the fact that, in Hong Kong, MNOs' demand for mobile spectrum is much greater than the supply of this spectrum.

In general, spectrum trading is unlikely to have a significant impact on improved spectrum efficiency in Hong Kong. Existing spectrum management tools, i.e. spectrum re-assignment in the case of 1.9–2.2GHz and 900/1800MHz bands, and mobile network sharing arrangements (including capacity leasing) may be equally or more effective in promoting greater spectrum efficiency. Capacity leasing arrangements confer some flexibility for operators to obtain additional network capacity to adapt to changes in market demand as and when required. The constrained supply of spectrum in the market indicates that existing operators' willingness to supply spectrum in prospective trades may be questionable.

There is an argument that spectrum trading may allow prospective new players and/or existing MVNOs to acquire spectrum outside of the primary assignment and increase effective competition in Hong Kong. Feedback from MVNOs interviewed, however, suggests that they have not yet considered such an approach in detail. Some of the benefits of a spectrum trading regime can also be conferred in a regime without spectrum trading. Spectrum auctions are conducted from time to time, and interested parties, including the MVNOs, are permitted to participate in the auctions to obtain spectrum.

The introduction of spectrum trading may give rise to public concern, if there is a perception of windfall gains occurring. Spectrum holders will have more opportunities to realise the changes in their spectrum holdings' value and profit from sale of the spectrum. Safeguards such as tax rules and spectrum usage fees can be used to mitigate the risk, but this may lead to loss of efficiency. There may also be public concern as to whether commercial entities are given undue privileges to reap additional profits out of what is considered a scarce and public resource.

Auction dynamics may also become distorted, albeit minimally, with the knowledge of divestment opportunity, and potential windfalls/private profits that may be achieved.

The introduction of spectrum trading may accentuate potential competition concerns such as spectrum hoarding and over-concentration of spectrum, though competition safeguards such as spectrum caps and competition laws are in place. There are also harmonisation and interference concerns, though they can be mitigated by clearly defining the technical specifications for spectrum use.

International examples of markets employing spectrum trading also show that significant time and effort will need to be dedicated to set up a spectrum trading regime. The existence of a spectrum

trading regime will likely result in an increase of the types of spectrum that can be held by individual operators. Over and above the additional administrative effort required to set up a spectrum trading regime, there is therefore an additional cost on the NRA to regulate prospective spectrum trades, specifically the concerns regarding competition, harmonisation and interference. The merits of introducing a trading regime should be considered against the time and effort involved, and the expected volume of trading.

Even if a trading regime is introduced in Hong Kong, there is likely to be a low level of short-term trading activities. Several benefits relevant in overseas jurisdictions also may not be applicable in Hong Kong. Considering the experience of other jurisdictions where spectrum trading regimes have been set up, the benefits expected in the short term in Hong Kong may not justify the costs. In this regard, there is limited justification to support the setting up of a spectrum trading regime in the short term, having considered the time needed to implement, and the risks, and costs.

4.3 Medium-term assessment of spectrum trading regime

In the medium term (i.e. in the next five to ten years), 5G is expected to be the main driver for mobile spectrum usage and development. Spectrum trading may be a potential approach to facilitate the greater flexibility brought about by this new technology. However, there is still some uncertainty around how 4G networks will evolve to 5G, particularly since 5G standards are still developing and its use cases are not yet entirely clear. In this section, we will study the major trends in the medium term, to further understand whether a spectrum trading regime may play a role in the larger spectrum management framework in Hong Kong.

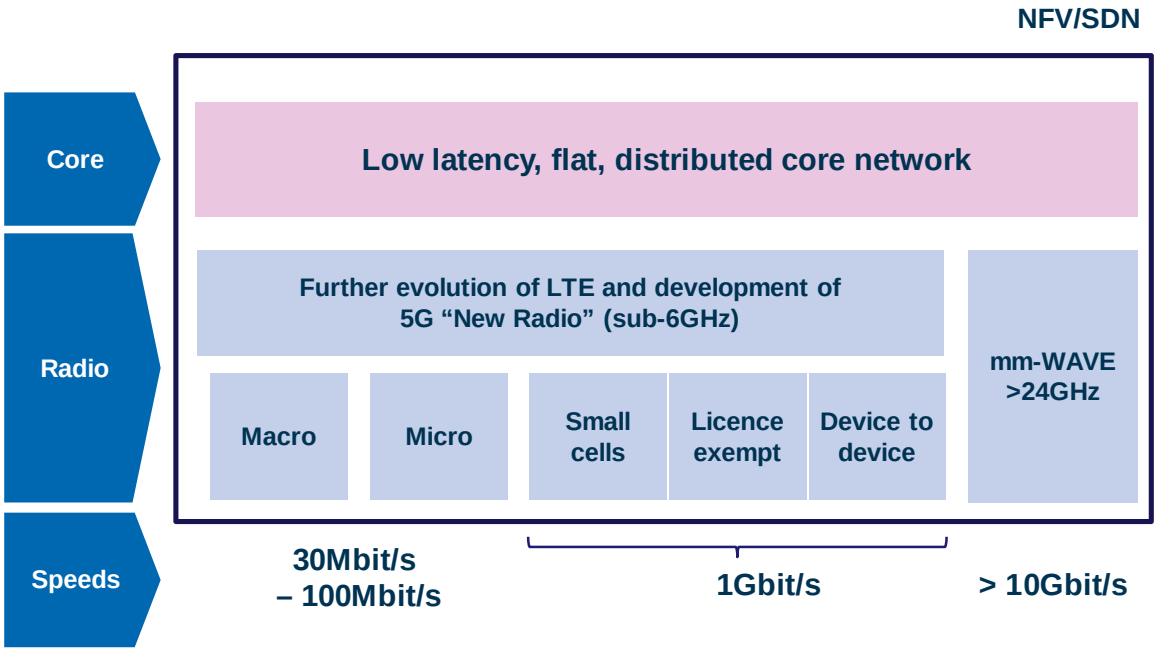
4.3.1 State of 5G evolutions

5G proposes a new radio interface, 5G-NR, and a new, virtualised core architecture for mobile networks, as shown in Figure 4.6. Other key elements of 5G include greater densification (e.g. dense deployment of small cells) and software control of the RAN and the core through network function virtualisation (NFV) and software-defined networking (SDN) technologies. A flat core network is proposed to achieve very low-latency connections and flexibility in deployment, and to facilitate better integration between different access technologies (wireless and wired). However, in the initial stages of 5G roll-out, networks are expected to use 5G-NR in new spectrum bands, in conjunction with 4G RANs and 4G core networks. Flexible spectrum usage is envisaged such that operators might opt to deploy mobile uplinks and downlinks in different ways to meet market demand (e.g. 5G-NR downlinks in a higher frequency band, combined with LTE uplinks in a lower band). In the ‘non-standalone’ mode of 5G deployment, operators will utilise existing 4G networks to provide core network functionality. In the alternative ‘standalone’ mode, operators will deploy new virtualised core and radio networks.

One of the core targets of 5G is to provide wireless connectivity for a wide range of services and applications in various industry verticals, on top of improving network performance from previous generations of mobile technologies. The overall evolution to 5G is aimed at enabling networks to

become more flexible and suitable to take on some of the new applications and use cases foreseen within the 5G era.

Figure 4.6: Evolution of mobile networks towards 5G [Source: Analysys Mason, 2018][55]



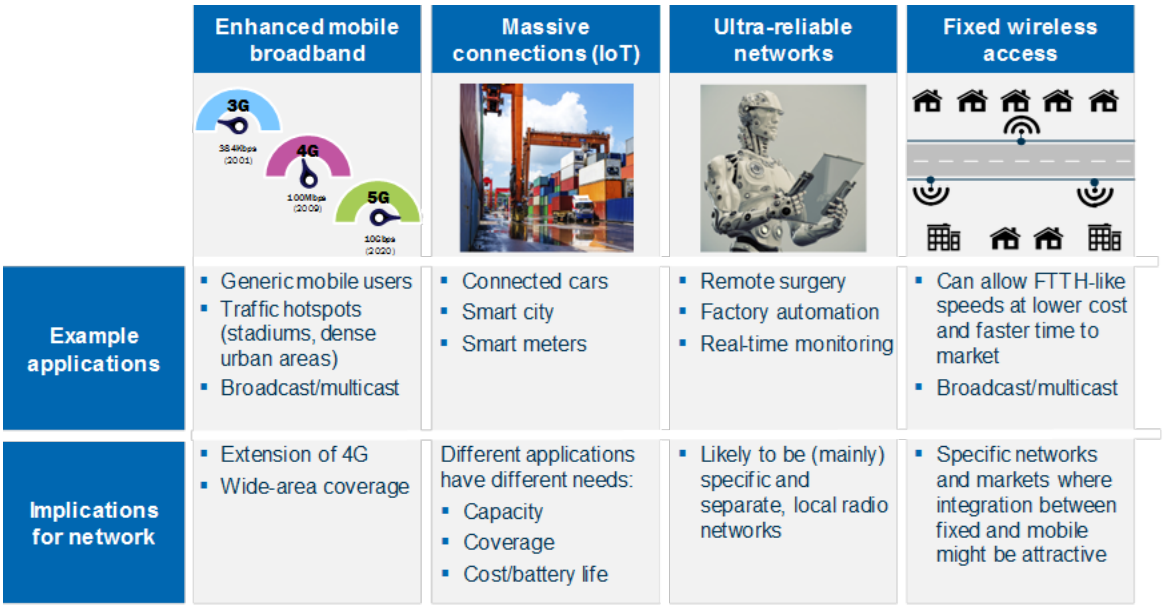
Various international forums (including the ITU-R) have endorsed use cases for 5G, which can be grouped into four categories:

- enhanced mobile broadband
- 'massive connections' (IoT)
- ultra-reliable networks
- 5G fixed-wireless access.

The different possible use cases for 5G have differing implications on how mobile networks might need to evolve, as illustrated in Figure 4.7 below.

55 NFV: network function virtualisation; SDN: software-defined networking.

Figure 4.7: Impact of 5G use cases on network development [Source: Analysys Mason, 2018]



The different 5G categories will potentially support a wide range of industry verticals and use cases. 5G networks might support industry verticals such as the following:

- manufacturing, e.g. remote control of machinery, factory automation
- healthcare, e.g. remote surgery
- energy and utilities monitoring, e.g. smart meters, smart city
- transport, e.g. connected and autonomous vehicles, connected bus stops, connected buses.

The scale of standardisation required to achieve all envisaged use cases means that 3GPP, the international industry standardisation body for mobile networks and devices, has had to prioritise some use cases over others. The immediate standardisation priority within 3GPP Release 15 (pre-2020) is to complete standards for 5G enhanced mobile broadband. This suggests that in the initial phases of 5G roll-out (expected within the next three to five years), networks will be predominantly positioned to deliver better, faster mobile broadband services compared with today's 4G services. The next ITU World Radiocommunication Conference (WRC), which is to be held in 2019, will focus on harmonising allocations for the spectrum required for enhanced mobile broadband, including establishing IMT standards in selected bands under study in the spectrum above 24GHz.

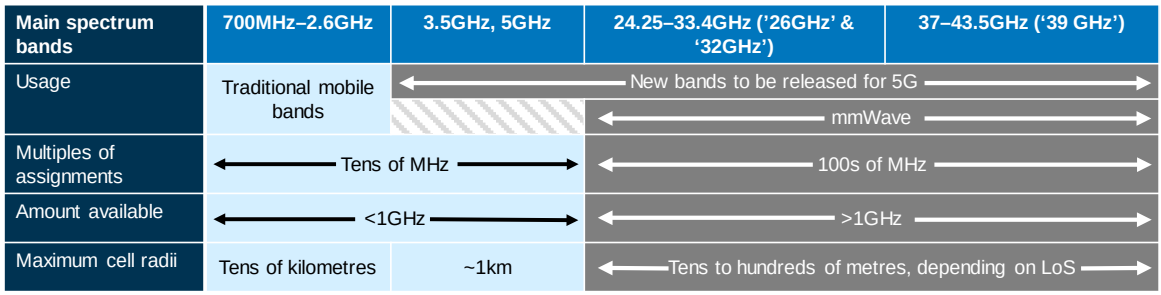
Subsequent iterations of the 3GPP standards (i.e. Release 16 onwards) are expected to expand capabilities towards the other envisaged use cases, including ultra-reliable networks, for which latency and network availability demands are particularly onerous. Spectrum harmonisation for these use cases will likely emerge only after 2023, at the next WRC.

Spectrum requirement for 5G

The implication of the different use cases and requirements that 5G networks are being designed to achieve is that networks will require more spectrum to provide services in future. Spectrum use is also likely to become more complex and may be quite different from spectrum use today.

Full 5G capability will likely require very wide bandwidth channels (e.g. multiples of 100MHz), although we understand that operation in narrower channels is also possible or necessary (e.g. in the sub-1GHz bands). In higher frequency bands in the millimetre-wave (mmWave) range, studies suggest that the spectrum needed per operator could be in the order of 400MHz or more. Currently, as in most markets in the world, wider contiguous channels are not available in existing mobile bands in Hong Kong. Hence, new spectrum in higher frequency bands is needed to deliver the full capabilities of 5G-NR. The implication is that, although mobile networks typically use spectrum in bands below 3GHz at present, 5G will additionally use much higher bands. The bands anticipated to be used in the initial deployment of 5G are shown in Figure 4.8.

Figure 4.8: Spectrum bands likely to be used for 5G [Source: Analysys Mason, 2018]



As shown in Figure 4.8, 5G spectrum bands will likely be a combination of existing mobile spectrum (700MHz–2.6GHz) and new bands, including mid-band spectrum (e.g. 3.5GHz, 5GHz) and mmWave spectrum (e.g. 26GHz, 28GHz, 31GHz, 40GHz). Spectrum from 45.5–86GHz is also under consideration by the ITU for WRC-19. Current mechanisms provide some flexibility to allow use of existing mobile spectrum (700MHz–2.6GHz) to evolve with the needs of 5G. In Hong Kong, mobile spectrum bands are generally assigned on a technology-neutral basis. Like the roll-out of 3G and 4G services in the last two decades, operators can re-farm their spectrum holdings for the future 5G technologies. The existing assignments of spectrum in the 2.5/2.6GHz and 2.3GHz bands will expire in the next ten years (in 2024, 2027 and 2028), providing opportunities for the CA to re-organise the band plans if necessary.

For the other spectrum bands identified in Figure 4.8 above, some frequency bands (e.g. the 3.5GHz and 26GHz bands) are currently assigned administratively to other services (fixed satellite services and fixed links) in Hong Kong. We note that the CA has announced plans to vacate the spectrum with a view to re-allocating it to mobile services.

As proposed by the ITU, there will be multiple GHz of new spectrum in the 24.25–86GHz frequency range for future 5G services. The WRC in 2019 will decide on additional 5G spectrum bands for

mobile broadband within this frequency range. It is very likely that the supply of 5G spectrum in this frequency range would be large, given that a total of 33.25GHz of spectrum is under study by the ITU for IMT.[56] Although demand is still uncertain at this stage, should it be the view of the CA that there are no competing demands for 5G spectrum in the primary assignment, pursuant to the Radio Spectrum Policy Framework, this spectrum may be assigned administratively. In such a scenario, spectrum trading is not relevant.

There are also other issues relevant to spectrum usage in a 5G environment, such as shared spectrum usage between different services. Since spectrum has already been allocated for other uses in new bands (e.g. satellite), 5G may be sharing spectrum. Novel spectrum management frameworks, including but not limited to spectrum sharing, spectrum leasing and dynamic spectrum access, may need to be developed to ensure spectrum can be efficiently shared between its various uses.

Future 5G spectrum needs may also include a combination of licensed and licence-exempt (unlicensed) spectrum access. For example, the 5GHz band – currently available on a licence-exempt basis in many markets worldwide – might be used seamlessly in future within mobile networks (e.g. using LTE-U and LAA). We note that the CA conducted a public consultation in February 2018 to solicit views from the public and the industry on making 580MHz of shared radio spectrum in the 5GHz band available for the provision of public services.

Use of higher-frequency bands will also become especially important, due to congestion in lower bands. Higher-frequency bands will also provide capacity for very high traffic volumes, with very high-speed, low-latency connections. In these higher bands, mmWave spectrum could potentially be used by operators simultaneously for access and for backhaul links. Hence other approaches may be required to manage spectrum use, with less prescriptive measures for interference management. In some markets, spectrum in the 66–76GHz range is being considered as a licence-exempt band for 5G (exploiting synergies with 'WiGig' technology that has already been developed to use this spectrum on a licence-exempt basis).

As transferability conditions are typically conferred through individual spectrum permissions, it is difficult to envisage how spectrum trading, in its current form, can directly contribute to scenarios involving shared or licence-exempt (unlicensed) spectrum. The issues and other potential spectrum-related challenges resulting from 5G evolution are complex and interlinked and cannot be administered in isolation. The CA should monitor the technology and market developments and the implications of these for the spectrum assignment regime, both in primary and potentially in secondary assignments, with a view to keeping its spectrum assignment regime up to date in the 5G era.

In summary, our view is that:

- It is very likely, based on international developments, that the supply of 5G spectrum in the high frequency ranges will be very large

56 Source: 5G roadmap: challenges and opportunities ahead, ITU-R and ITU-T, July 2017.

- Since 5G demand is still uncertain, in the absence of competing demands for high frequency 5G spectrum in the primary assignment, this spectrum could be assigned administratively (pursuant to the Radio Spectrum Policy Framework). In such a scenario, spectrum trading is not relevant

- There are also other issues relevant to spectrum usage in a 5G environment, such as shared spectrum usage between different services, and combination of licensed and licence-exempt spectrum access to meet market needs. Again, spectrum trading is not relevant (e.g. in the context of gaining access to licence-exempt spectrum)

4.3.2 Medium-term assessment – conclusion

In the medium term, the whole spectrum assignment framework in Hong Kong needs to be considered from a wider perspective. This should consider, amongst others, the licensing approaches and adaptation of licensing conditions in response to demands for 5G, as indicated in the previous section. Additional spectrum management considerations are likely to occur in relation to spectrum access for 5G use cases other than mobile broadband. Whilst the technological advances in mobile networks envisaged for 5G are such that multiple logical networks can be provisioned from one physical network (i.e. through slicing), it is possible that new spectrum demands will emerge (e.g. in relation to possible demand for private 5G networks for industrial IoT use cases). There might also be demand for private in-building 5G networks. There might be a need to consider more flexible approaches to spectrum assignment.

That said, a significant overhaul of the existing spectrum assignment framework for mobile spectrum is unlikely to be needed in the next three years whilst the industry is focussed on supporting the enhanced mobile broadband use case. Moreover, the current mechanisms already provide some flexibility to allow use of existing mobile spectrum to evolve with the needs of 5G (e.g. re-farming of technology-neutral spectrum holdings for future 5G technologies). The expiry of existing spectrum assignments within the next ten years also provides opportunities for the CA to reorganise the band plans if necessary before the new term of assignment. Hence, there might be limited justification to support setting up of a spectrum management regime for the medium term, even in the face of technology changes in the early 5G era.

In the interim, the NRA’s utmost priority should be to ensure there is enough primary supply of 5G spectrum in the market for the initial deployment of 5G. The CA should therefore continue its focus on working together with regional and international communities to identify and harmonise potential 5G spectrum and ensure the timely availability of spectrum in these newly identified, harmonised bands.

5 Proposed approach to spectrum trading implementation if pursued, and alternative methods to enhance the spectrum efficiency in Hong Kong if not pursued

In this section, we draw from conclusions in Section 3 of the report and propose recommendations on how a spectrum trading regime could be introduced in Hong Kong (if such a regime were pursued).

We will also consider how the government can enhance the efficient use of spectrum by methods other than introducing a spectrum trading regime.

5.1 Summary of our views on spectrum trading and other non-trading mechanisms to enhance efficient use of spectrum

The introduction of spectrum trading in Hong Kong appears to be a balancing act among (a) an increase in flexibility in the overall spectrum assignment regime in terms of permitting asymmetric trades (including partial trades of spectrum holdings) and increased time flexibility for operators to determine when to acquire or relinquish spectrum, (b) costs and potential risks associated with spectrum trading, and (c) safeguards and further regulatory controls required to forestall/alleviate such costs and risks and the related implementation costs.

In Section 4.2.4, we concluded that there is no critical bottleneck in Hong Kong that would require spectrum trading as a remedy in the short term (over the next one to five years). The current spectrum management framework for public mobile telecoms services appears to be reasonably effective in promoting the efficient use of spectrum under existing regulatory mechanisms (e.g. assignment/re-assignment opportunity at regular intervals, capacity leasing mechanism). We also note that as spectrum for public mobile telecoms services is relatively well utilised in Hong Kong, the supply of mobile spectrum for trading and trading activities is anticipated to be low in the short term.

The implementation timeline required to set up the spectrum trading regime is an important consideration in the short term. Various jurisdictions have dedicated a significant amount of time to set up spectrum trading regimes. Given the time it takes to set up and the availability of existing regulatory mechanisms (including assignment/re-assignment opportunities at forthcoming auctions), the window of opportunity for a spectrum trading regime to have an impact on the Hong Kong market may be limited in the short term.

In the medium term (the next five to ten years), mobile spectrum usage and development is expected to evolve further because of 5G. Additional flexibility brought about by spectrum trading may be useful to cope with 5G development and roll-out. However, potential 5G spectrum-related challenges are likely to be complex and interlinked and thus there has yet to be a clear case for implementing spectrum trading in Hong Kong even for the medium term. The CA should monitor

the technology and market developments and the implications on the spectrum assignment regime for mobile services in the 5G era.

Spectrum trading may be a useful tool to enhance spectrum flexibility and efficiency, but there are also other spectrum management tools that can be used. The other tools could also potentially be enhanced to achieve similar benefits to the introduction of spectrum trading, namely facilitating more efficient use of spectrum.

We discuss the potential implementation of spectrum trading in Hong Kong in Section 5.2, and alternative mechanisms to enhance spectrum use in Hong Kong in Section 5.3.

5.2 Recommendations for Hong Kong to implement spectrum trading

In this section, we advise how a spectrum trading regime could be introduced, assuming a trading regime is to be pursued in Hong Kong. We have drawn on recent international experience on spectrum trading to recommend the following approach to spectrum trading implementation in Hong Kong. Our recommendation discusses the following:

- Scope for a spectrum trading regime to enhance spectrum efficiency
- Proposed process for Hong Kong's spectrum trading regime
- Key implementation considerations
- Safeguards for spectrum trading issues.

5.2.1 Scope for a spectrum trading regime to enhance spectrum efficiency

In our definition of the scope of spectrum trading in Hong Kong, we consider areas including spectrum permitted for trading, types of transactions permitted, parties eligible to trade and rights and obligations of the newly tradeable spectrum.

Spectrum permitted for trading

Spectrum trading is a mechanism that complements existing market-based primary assignment, e.g. competitive auction. In Hong Kong, market-based assignment is only adopted to assign spectrum with competing demands, i.e. spectrum for public mobile telecoms services and wireless broadband services. Therefore, only such spectrum should be permitted for spectrum trading in Hong Kong.

Types of transactions permitted

We recommend that all types of transactions be permitted under the spectrum trading regime if one is implemented in Hong Kong; these types would include full spectrum transfer, partial transfer and spectrum leasing. Theoretically, all these trade types would help improve spectrum utilisation and efficiency in the Hong Kong market.

Parties eligible to trade

The spectrum trading regime should adopt existing spectrum management policies as far as possible to minimise disruption to the existing framework. Parties eligible to trade in the secondary market should be consistent with the parties eligible to participate in the primary assignment.

At present, the CA imposes general restrictions on the eligibility of bidders at primary assignments. To be eligible as a qualified bidder, the bidder must comply with or can comply with rights and obligations that apply to the spectrum and is not connected to another bidder. Enforcing this same guideline in the spectrum trading regime means that the parties involved will have greater clarity on their eligibility to trade in the secondary market.

No additional restrictions should be introduced on the party eligible to trade. Additional restrictions may prevent a new entrant from buying spectrum that it may be able to use more efficiently than existing players. If trading is restricted to incumbents, then potential efficiency benefits associated with innovation and competition may be lost.

Like new entrants attaining spectrum at the primary assignment, buyers without existing carrier licences should be required to obtain the necessary licences from the CA to be able to use the frequency spectrum that they have acquired in the secondary market. As UCLs and spectrum assignments are intrinsically linked in Hong Kong, obtaining a UCL should be a necessary step to affect a potential trade.

Rights and obligations of tradeable spectrum

Generally, all rights and obligations that apply to frequencies being transferred should also be transferred to the buyer in any outright spectrum trade and there should be no change to the overall set of rights and obligations.[57] This includes the roll-out obligation before a specified deadline as well as the obligation to maintain the coverage thereafter. This is to prevent the creation of legal loopholes which may distort the primary market for spectrum and to ensure that public policy goals linked to service-related obligations will continue to be fulfilled. It also avoids undue uncertainty for both the buyer and seller on how traded frequency bands can be used and what risks the buyer is taking on in relation to obligations that must be fulfilled.

By transferring the rights and obligations along with the spectrum assigned in the trade, the CA can maintain control of the spectrum assignment in the new trading environment and avoid/mitigate potential disruption and uncertainty over interference environment for third-party operators.

57 If spectrum leasing is considered, it is possible that the original licensee remains responsible for any licence obligations being met.

5.2.2 Proposed process for Hong Kong's spectrum trading regime

As discussed, we do not expect a high volume of spectrum trade in Hong Kong. A process akin to that of Category 2 case study markets (e.g. Singapore, Switzerland and Luxembourg) could therefore be adopted in Hong Kong without risk of significant loss of benefit compared to more extensive implementation of a trading regime. All prospective trades shall be reviewed on a case-by-case basis, which will allow each trade to be considered on its relevant technical merits.

Notification of intention to trade

Both trading parties should submit a joint application to the CA with the following basic information to notify their intention to trade:

- Identity/contact details of trading parties
- Spectrum assignment to be traded (total/partial transfer)
- Proposed start and end date of transfer (if it is an outright sale, the end date will be the expiry date of spectrum assignment)
- Pricing and other terms
- Service-related information (including handling of licence obligations and interference management)
- Justification of trade (technical benefits, e.g. reduction of interference, improvement in spectral efficiency and introduction of new or innovative services)
- Competition assessment that the proposed trading does not give rise to material competition concerns.

Approval process

The CA may publish the intention to trade to give the telecoms industry and other affected parties the opportunity to submit comments on the proposed trade. The suggested period for this public consultation can be between three weeks to one month to allow for sufficient time to garner public responses. Simultaneously, the CA should conduct an internal review of trade.

To streamline the CA's efforts to review the trade, a two-tier approval process can be used, involving the following:

- *Preliminary*: The CA should commence a preliminary review of trade using the current competition and interference management frameworks and regulations at the time when the public consultations are held to solicit feedback on the proposed trade. If there is evidence of possible distortion of competition, or potential interference violation, based on CA's preliminary assessment and public consultation responses, a secondary assessment is required.

- *Secondary*: Extended in-depth examination by the CA involving experts on economics and competition law to review any competition concerns (including position of trading parties in the relevant downstream service markets and downstream prices), and radio engineering experts for

interference concerns. More information can also be sought from trading parties as and when required.

The assessment should arrive at one of the following conclusions:

- the trade should be rejected, with an explanation provided publicly for the grounds for rejection; or
- the trade should be accepted, approval should be announced publicly, with the CA providing justification for this decision. Approval of the trade may be accompanied by further stipulations and/or conditions, such as how licence obligations are to be transferred.

If the trade is approved, the CA can proceed to update the spectrum holdings of the trading parties (if the trade involves only existing carrier licences holders), and issue new carrier licences if a new entrant has acquired spectrum via the trade. In cases where the trade involves a reconfiguration of the spectrum assignments, then interference limits, spectrum boundaries or service obligations may also need to be amended.

5.2.3 Key implementation considerations

Any trading regime introduced in Hong Kong should build on the existing regulations and practices currently adopted by the government to minimise implementation complications resulting from inconsistencies with the existing spectrum management framework.

Specifically, Section 32H (2) of the TO allows the CA to assign frequencies to holders of carrier licences and General Condition 2.1 of the UCLs held by the MNOs allows spectrum holders to transfer the licences or any right or permission within it to another party, with the consent of the CA. However, legislative changes may be required to implement the necessary safeguards, and additional covenants may need to be added to carrier licences to allow spectrum assigned under the licence to be tradable.

5.2.4 Safeguards for spectrum trading issues

While spectrum trading brings about increased flexibility and encourages better spectrum utilisation, there may be additional costs/risks because of the implementation of trading. Safeguards are required to forestall/alleviate any costs/risks associated with spectrum trading.

The two-tier approval process proposed in Section 5.2.2, which includes a competitive assessment, is a key safeguard against potential costs/risks from the implementation of trading. It provides the CA with the discretion to prevent trades that may have an effect on foreclosure of competition, i.e. trades that contribute to anti-competitive spectrum hoarding or the over-concentration of spectrum. In cases where the trade did not give rise to competition concerns at the time of approval, but anti-competitive conduct was observed after the trade, the concerned party or parties will be subject to existing ex-post mechanisms, specifically the competition rules under the CO. This adequately mitigates competition concerns, both pre-trade and post-trade.

Secondary review of trades involving radio engineering experts will also help address concerns regarding loss of harmonisation and risk of interference. This review should place similar levels of scrutiny as that to approve technical changes of licensing conditions. Trades that will cause a material loss of harmonisation and/or could substantially increase the risk of interference and are not commensurate with the efficiency gains to be gained from the redeployment of spectrum should be rejected.

Additionally, in Hong Kong's current spectrum management framework, harmonisation and interference issues are already safeguarded at the primary assignment stage. Spectrum assignments are typically sized in a way that would make the whole or most of it necessary for the intended use, to avoid the loss of harmonisation. Technical conditions are also clearly defined to control the risk of interference.

Other pre-existing safeguards in Hong Kong, i.e. network and service roll-out requirements, can also help safeguard against other costs arising from the introduction of spectrum trading, namely spectrum speculation and the distortion of auction dynamics. Roll-out requirements, tied to a performance bond, will compel an operator to deploy network services as intended, preventing spectrum resources from being left idle, as in the case of pure speculative hoarding. The transfer of rights and obligations under the spectrum assigned in spectrum trades, described in Section 5.2.1, seeks to further ensure that the trading mechanism will not be exploited for speculative purposes. However, should there be speculative activity despite the safeguards, the regulator would likely not be able to prevent the additional costs from passing on to consumers as service charges are purely commercial decisions of the operators and are not regulated in the free market.

We note that safeguards may not be effective in eliminating all potential costs/risks. This is particularly evident for the risk of windfall gains and other private profits to be gained by trading parties. Although a tax on windfall gains was considered by some spectrum trading economies as a safeguard against the prospect of profiteering from spectrum trades, no market had implemented a form of spectrum trading tax. This reflects the difficulties involved in changing regulations to legitimise issuance of such a tax, and the complications in quantifying the amount of tax/fees that should be charged.

Regulatory review of trades may test for 'unequitable profiteering', reducing the risk of operators involved receiving windfall gains and other private profits from spectrum trading. However, this will not comprehensively resolve the issue of profiteering, as approved trades can still be conceived as 'unfairly benefiting' trading parties. As can be seen, no approach is entirely satisfactory as a safeguard against the prospect of profiteering from spectrum trading. This is one of the key concerns that is yet to be addressed satisfactorily.

5.3 Alternative mechanisms to enhance spectrum use in Hong Kong, without implementing spectrum trading

Other than spectrum trading, there are other mechanisms that can be also used to create a more flexible environment for spectrum re-assignment and enhance spectrum efficiency in the Hong Kong market.

We have drawn on existing regulatory frameworks, and propose the following three enhancements to current spectrum management mechanisms that could help enhance spectrum use in Hong Kong, without implementing spectrum trading, namely:

- Enhanced mobile network sharing arrangement
- Periodically adjusted SUF for administratively assigned spectrum
- Enhanced spectrum swap.

5.3.1 Enhanced mobile network sharing arrangement

Existing mobile network sharing arrangements can be enhanced to increase ease of spectrum capacity leasing and facilitate increased flexibility in network deployment.

Current situation

At present, various forms of mobile network sharing are permitted and implemented in Hong Kong.

For example:

- **RAN sharing**: MNOs may through commercial arrangement share all or part of RAN equipment and facilities, antennas and sites. However, spectrum pooling between two MNOs is prohibited and RANs of each MNO is required to be logically separate. MNOs may negotiate and agree among themselves on RAN-sharing arrangements without intervention by the CA, if they are not in breach of the restrictions and obligations imposed by the law and their carrier licences. There are also no restrictions on MNOs for outsourcing of operation and maintenance of their core network and RAN to another MNO or third-party service providers.

- **Capacity leasing to MNO/MVNOs**: Flexible capacity leasing through commercial arrangement between MNOs or with MVNOs is permitted and has been implemented in Hong Kong. This is established to allow a tenant MNO or MVNO to expand its service coverage for an area or enhance its network capacity for its own subscribers and increase utilisation of the lessor's spectrum. Existing framework mandates MNOs to only transmit using their own assigned spectrum as specified in their respective licences, and lease out only network capacity. Some MNOs/MVNOs have reflected that they lack control over where spectrum is to be deployed via this mechanism, thus coverage and/or capacity may not be available in areas that they need most.

Proposed enhancement

Radio network capacity can be leased to another MNO through a combination of existing RAN-sharing and capacity leasing mechanisms. This will allow the tenant MNO to have more control over how the lessor MNO's spectrum should be deployed.

Under the enhanced radio network capacity leasing agreement:

- MNO A can appoint MNO B to deploy the network for a particular spectrum band that it wishes to lease (to MNO B).
- MNO B can then deploy MNO A's spectrum on its own RAN equipment through RAN sharing, while upholding regulatory requirements for the logical separation of its existing network and the network that it is deploying on behalf of MNO A and restrictions on spectrum pooling.

As MNO A maintains legal control and thus owns the network capacity arising from the spectrum, it can then lease the network capacity from the spectrum band back to MNO B. No changes will be required to regulatory and licensing conditions on the spectrum band under the enhanced spectrum capacity leasing agreement.

This will increase MNO B's flexibility in deploying MNO A's spectrum according to its own coverage and capacity demand. As the arrangements can be made on demand without intervention by the CA, the spectrum user will have greater timing flexibility to increase or decrease network capacity in required areas in response to changing market demands.

Other benefits of allowing a combination of RAN sharing and capacity leasing might include the reduction of upfront deployment costs from minimising duplication of infrastructure and increased provision of carrier aggregation across the market to enable the provision of higher-speed mobile data services to subscribers.

Key implementation considerations

Additional safeguards may be needed to maintain consistency with existing regulatory requirements, including prohibition of de facto spectrum leasing through enforcement of the requirement to have logically separate RANs. These can include the requirement to notify and seek approval from the CA in the case of long-term capacity leasing agreements (e.g. more than five years) to prevent the scenario where an MNO allows another MNO to use its spectrum for the entire assignment duration.

5.3.2 Periodically adjusted SUF for administratively assigned spectrum

An annual SUF can be charged for mobile spectrum that is assigned administratively and periodically adjusted, to better reflect the market value and opportunity cost of the spectrum. This can facilitate spectral efficiency, as spectrum users are incentivised to use their assigned spectrum in a more efficient manner and might return any unutilised spectrum (e.g. for re-assignment to other spectrum users).

Current situation

At present, users of mobile spectrum pay a SUF at a level that is fixed for the entire assignment duration. Generally, as mobile spectrum is usually subject to competing demands, the SUF is determined by a competitive auction process, to determine a market value at the point of spectrum assignment. This market-based approach to primary assignment ensures that spectrum falls to the

operator that can extract the greatest value from the spectrum (and thus is willing to pay the most). When a full-fledged market-based approach is not used, e.g. for spectrum assigned based on offering rights of first refusal, the SUF will also aim at reflecting the full market value of spectrum, and reference may be made to past auction benchmarks which take into account local factors (such as the business environment and the associated cost of building and maintaining a mobile network in Hong Kong).

Relevant current spectrum management legislations for administratively assigned spectrum include the SUF charging scheme for fixed links, ENG/OB links and satellite uplinks, which took effect from January 2018 and will gradually phase in over the next five years. Prior to this legislation, no SUF was applicable for the use of spectrum with no competing demands and assigned administratively. With the legislation of the charging scheme, an annual fee will be levied on the usage of administratively assigned spectrum that is subject to payment of SUF. The current pricing methodology is the least cost alternative (LCA) approach, where prices are set based on the lowest cost incurred by an operator to provide the same service using alternative means. The level of SUF will be reviewed every five years to reflect changes in value of spectrum over time. Users of spectrum are thus encouraged to make more efficient use of their assigned spectrum and return any excess to the CA for re-assignment to other (more efficient) users.

The current charging scheme mandates only 'congested' frequency bands[58] to be subject to the payment of SUF. Therefore, SUF is only applied to very small set of frequencies[59] allocated for fixed links, ENG/OB links and satellite uplinks. Mobile spectrum, which is generally deemed to have competing demands and assigned via market-based mechanisms, does not fall into this category.

Rather than using a market-based approach such as a competitive auction for a fixed number of licences, we note the possibility of a different approach to future mobile spectrum assignment, particularly for 5G spectrum in the high frequency bands (i.e. mmWave). The CA has plans to make "*spectrum within the contiguous bandwidth of 4.1GHz in the 26GHz and 28GHz bands … available as the first batch of 5G spectrum for the market*" and has called for inputs to "*gauge the demand of the local industry … to facilitate CA's consideration of the allocation and related assignment arrangements for such spectrum.*"[60] This might reflect that the potentially large supply of mmWave raises uncertainties on the extent of competing demands for the spectrum in the primary assignment. According to the Radio Spectrum Policy Framework, spectrum that has no competing demands will be assigned administratively.

58 Defined as a frequency band with a utilisation rate of 75% or more which is anticipated to become more congested in the future.

59 Designated frequency bands are 2055–2095MHz, 5875–6425MHz, 6425–7100MHz, 7421–7900MHz, 8275–8500MHz and 10 700–11 700MHz.

60 Source: CA Invites Interested Parties to Express Interest in Using Spectrum in 26 and 28GHz Bands for Provision of Fifth Generation Mobile Services, Press release by the CA, 7 Dec 2017.

Proposed enhancement

If future mobile spectrum is assigned administratively, an annual SUF can be charged, reflecting the market value of the spectrum and opportunity cost. By charging SUFs annually instead of a lump sum fee for 15-year duration at the point of (re-)assignment in the case of mobile spectrum assigned through market-based mechanism, operators will be conferred greater timing flexibility in determining when to acquire or relinquish spectrum holdings. As this brings about considerable opportunity for spectrum users to respond to market changes, the benefit of increasing flexibility for spectrum use to evolve with changes in market demands can be achieved.

Framework for charging annual SUFs for mobile spectrum can be largely based on the current SUF charging scheme for fixed links, ENG/OB links and satellite links.

► *Level of SUF*

Annual SUFs for future administratively assigned mobile spectrum should adequately reflect the market value of spectrum at the point of time of award. The SUF can then be periodically adjusted to reflect changing value and/or developments in market demand, as noted above.

Spectrum prices can be determined based on business modelling and/or benchmarking:

- **Business modelling**: Typically using the discounted cashflow approach, to estimate the limit of what an operator will be willing to pay for the spectrum. Various economic, demographic, market, technical and network factors can be used to project the future cashflows from the use of the spectrum for a service over time. The net present value of these cashflows will give an indication of valuation of the spectrum by individual operators.

- **Prices in the open market in overseas jurisdictions (if available)**: Observed market valuations for similar spectrum bands in other jurisdictions can provide an indication of the market value of the spectrum. However, as market valuations vary based on time, geography and type of service, it should be interpreted with care.

Based on changes in market circumstances, the level of SUF should be periodically adjusted, allowing parties who value the spectrum less than the market to surrender their spectrum holdings to the CA for re-assignment to a party that values the spectrum at or above market value. Currently, a review is conducted every five years to account for changes in value of spectrum over time.

► *Coverage*

Like current SUF charging scheme, only ‘congested’ mobile spectrum should be subject to the payment of SUF.

Under current definitions, ‘congested’ spectrum is defined as a frequency band with a utilisation rate of 75% or more which is anticipated to become more congested in the future. The CA determines the potential for congestion via a basket of factors, including past and future demand and supply,

utilisation trend of that frequency band, market and technological development and other viable alternatives.

Key implementation considerations

This proposed mechanism is not considered for spectrum with competing demands and to be assigned via auctions. This is because the prospect of annual, periodically adjusted SUF may result in a distorting effect on auction prices, to account for uncertainties in future cashflows from the use of the spectrum over time.

For mobile spectrum with competing demands and assigned via auction, the current mechanism to charge SUF for the entire licence duration at the point of assignment/re-assignment should remain unchanged.

5.3.3 Enhanced spectrum swap

In Hong Kong, current frequency assignment exchange mechanisms appear to restrict swaps to spectrum in the same band, and of the same bandwidths. Enhancements can be made to potentially permit cross-band, asymmetric swaps if there are grounds for technical or market efficiency. This may help achieve the benefits of rejuvenation of underutilised spectrum and flexibility to allow spectrum use to evolve with market demand.

Current situation

Subject to the CA's approval, frequency swaps are currently allowed on the grounds of enhancing technical efficiency in spectrum deployment (e.g. reduction of radio interference, improvement in spectral efficiency and introduction of new or innovative services). In recent auctions, specifically the auction of spectrum in the 1.9–2.2GHz band (2014) and the upcoming 900MHz and 1800MHz spectrum re-assignment, a five-year moratorium has been imposed on spectrum swaps. This is mainly to promote competitive bidding at the auction.

Approval for spectrum swaps is granted by the CA on a case-by-case basis, with each proposed swap also subject to conditions such as no monetary transfer, no/minimal impact to underlying licence obligations and commitment and minimal impact on (related) services provided to customers.

There are two precedent cases of frequency swaps approved by the CA, involving spectrum of the same band and same bandwidth:

- between CMHK and SmarTone of 3.2MHz of spectrum in the 1800MHz band in 2012
- between CMHK and HKT of 10MHz of spectrum in the 2600MHz band in 2016.

Proposed enhancement

The spectrum swap mechanism can be enhanced to permit inter-band and/or asymmetric bandwidth spectrum swaps if there are ground of technical efficiency.

Inter-band and/or asymmetric spectrum swaps can help improve flexibilities of spectrum use to adapt to changes brought about by technology evolution. Permitting asymmetric swaps of spectrum will create more options for operators to reorganise their existing spectrum holdings to form spectrum with wider bandwidth, thereby achieving greater technical efficiency in the deployment of spectrum.

Additionally, this enhanced mechanism can also increase the opportunity for operators to aggregate fragmented spectrum holdings, reducing the adjacent channel interference and facilitating gains in spectral efficiency.

The proposed enhancement should not counteract other public policy objectives in the Hong Kong market. This includes promotion of competitive bidding at primary awards through a moratorium on spectrum swaps. We therefore recommend that similar five-year restrictions should be placed on enhanced spectrum swaps. However, the CA should continue to maintain discretion to respond to requests for swaps, especially in scenarios where enforcing the moratorium would prevent a transaction that has clear technical benefits and will increase overall spectrum efficiency in the market (e.g. if the outcome of an auction has resulted in an undesirable outcome, such as in relation to spectrum fragmentation).

► *Proposed process*

Each prospective cross-band, asymmetric swap shall be reviewed on a case-by-case basis, to allow each transaction to be evaluated on its own technical merits. Both parties should submit a joint application to the CA containing the following information:

- Identity/contact details of parties involved in the swap
- Spectrum assignment to be swapped
- Proposed start and end date of the spectrum swap
- Justification for the swap (relevant technical merits, market efficiency gains).

Based on the information provided, the CA shall conduct an internal assessment of the proposed spectrum swap. The assessment criteria for the enhanced spectrum swap process can be adapted from the current assessment criteria for spectrum swaps, in order not to create loopholes in the current spectrum swap process. As such, the CA should consider the following when reviewing prospective enhanced spectrum swaps:

- Whether the proposed spectrum swap involves any monetary exchange between the parties

- Whether the values of the spectrum to be swapped are comparable (e.g. based on inflation-adjusted auction prices, recent market and technology developments)

- Whether greater technical or market efficiency can be achieved because of the proposed spectrum swap
- Whether the proposed spectrum swap will affect the rights and obligations tied to the spectrum assignment, including the expiry date of the frequency assignments, payment of SUFs and other licence fees, and network and roll-out requirements
- Whether the proposed spectrum swap will result in the transfer of licence obligations and conditions applicable to the concerned spectrum between the parties
- Whether there will be significant impact on customers due to the swap (e.g. service interruption to services provided by the parties to both downstream end users and MVNO customers), or cause interference to services provided by other MNOs to their customers).

The assessment should arrive at one of the following conclusions:

- the spectrum swap should be rejected, with an explanation provided to the parties involved for the grounds for rejection; or
- the spectrum swap should be accepted, and the approval should be announced publicly including justification for the approval.

If the swap is approved, the CA can proceed to amend the UCL held by the parties involved to give effect to the proposed spectrum swap.

Key implementation considerations

There is a risk that inter-band and/or asymmetric spectrum swaps may have the effect of substantially lessening competition. For example, the swap of low band spectrum and high band spectrum between MNO A and MNO B may result in a concentration of low band spectrum with MNO A and high band spectrum in MNO B, which may affect the MNOs' ability to provide territory-wide quality services. Therefore, competition assessment is required in the ex-ante review process to ensure minimal distortion to competition in downstream markets.

Further, the likelihood of the spectrum swap being more beneficial to one party is increased if asymmetrical spectrum swaps are permitted. Additional care will have to be taken to prevent hidden monetary exchange from the proposed frequency swap. The government should reserve the right to audit inter-company transactions to ensure that other transactions between both parties in the spectrum swap is fair and there is no de-facto monetary exchange.

6 Conclusions

In this report, we have considered the benefits and costs of introducing a spectrum trading regime in Hong Kong. We have reviewed international examples of implementation of spectrum trading in other jurisdictions, and also examined and compared these with the spectrum management framework in Hong Kong. We have also considered possible approaches to spectrum trading implementation, and alternative methods to enhance spectrum efficiency in Hong Kong in lieu of a system of spectrum trading.

6.1 Latest overseas experience in respect of spectrum trading

Spectrum trading is applied in some markets as a complementary mechanism to market-based primary assignments. It provides additional flexibility for the market to re-distribute spectrum resources as and when opportunities for more efficient use arise and transfers may be needed to enhance the efficiency of spectrum use.

Based on comprehensive research into the extent of implementation of spectrum trading in different markets worldwide, we have identified three major scenarios with respect to the implementation (or otherwise) of spectrum trading, namely:

- **Category 1**: A clear spectrum trading regime is implemented through specific legislation – examples in this category include the UK, USA, Canada, Australia and New Zealand.
  NRAs clearly define the forms of trading that may take place, including:
  — total or partial spectrum transfer
  — trading with or without liberalisation (service neutrality)
  — trading of licences with or without technology neutrality
  — permission to lease
  — allowance for monetary transfer to occur to compensate for asymmetric trades
  — requirement for regulatory pre-approval
  — competition law/guidelines to address possible anti-competitive practices.

  We note that setting up a clear spectrum trading regime typically requires significant effort and commitment on both the spectrum assignment authority and the industry.

- **Category 2**: Spectrum trading is possible, albeit not through a full-fledged trading regime – examples in this category include Singapore, Luxembourg and Switzerland. NRAs typically adopt a case-by-case approach to assess prospective spectrum trades. The case-by-case approach means that there is some ambiguity on procedure and assessment criteria, and on what is permitted and what is not permitted.

- **Category 3**: No spectrum trading is possible – examples in this category include Japan and Mainland China. NRAs in Category 3 markets usually take a more proactive role in managing spectrum utilisation and efficiency, such as adapting licensing rules and frameworks to suit a

default non-trading stance. These NRAs review prospective transfers in a limited set of scenarios to achieve the similar objectives of promoting the efficient use of spectrum.

Hong Kong currently falls under Category 3.

International experience indicated that most markets with a trading regime (Categories 1 and 2) have experienced low levels of trade involving mobile spectrum. In the case of Luxembourg and Switzerland, no spectrum trades have ever been recorded.

In other markets with low volumes of spectrum trading, trading has been typically used to rejuvenate underutilised spectrum in instances where assigned spectrum was not fully used by the licence holder. Spectrum trading has also been used as a response to changing technology and service demands.

In Canada and the USA, regional spectrum licensing provided a strong incentive for trading to harmonise spectrum holdings, and large volumes of trade have been observed in these countries. This benefit is irrelevant to Hong Kong as Hong Kong does not have a regional licensing regime.

6.2 Supply of and demand for spectrum trading in Hong Kong

To provide an assessment of the supply of and demand for spectrum trading in the Hong Kong context, we have examined the current spectrum management regime in Hong Kong, including the alternative tools which could achieve similar benefits to those of the introduction of a spectrum trading regime, to gain insights on its effectiveness in ensuring optimal spectrum use. We have also assessed information on the latest market conditions derived from industry interviews.

6.2.1 Spectrum management in Hong Kong

Spectrum trading is not permitted in Hong Kong. Our review indicates that the current spectrum management framework in Hong Kong for public mobile telecoms services is reasonably effective in promoting the efficient use of spectrum. Our findings on the current framework are that:

- Different alternative arrangements to enhance spectrum efficiency are permitted under specific circumstances (this is discussed in further detail in Section 3.1.2 of this report). The acquisition of spectrum through M&A activities is also possible.

- A telecoms licensee is not allowed to resell or redistribute spectrum assigned under its licence to other parties. Licensees shall only transmit using their own assigned spectrum as specified in their respective licences, and the radio signal should be identifiable as the signal of that licensee. However, a licensee may have some forms of sharing of network capacity with other licensees.

- In the absence of trading, to prevent spectrum hoarding and/or under-utilisation, network and service roll-out obligations have been imposed on spectrum assigned. These may be in the form of a minimum number of commercial and/or residential buildings (where the scope of service in the licence include fixed service) and/or a coverage of the network and service provided to an area where at least a specified proportion of the population of Hong Kong live from time to

time (where the scope of service in the licence include mobile service). A spectrum assignee is also required to submit a performance bond as a guarantee for its compliance with its respective network and service roll-out requirements.

- The CO, a cross-sectoral competition law, has been fully implemented in Hong Kong since December 2015. The CA is conferred concurrent jurisdiction with the Competition Commission to enforce the CO in the telecoms and broadcasting sectors. Telecoms carrier licensees are subject to three competition rules: prohibition on agreements/practices to prevent, restrict or distort competition; rules pertaining to abuse of market power; and rules preventing mergers that have or might have the effect of substantially reducing competition.

- Under current legislation, licensees may submit frequency swap requests involving no monetary exchange to the CA for approval on a case-by-case basis. The CA has so far approved two requests for spectrum swaps between MNOs: between CMHK and SmarTone in the 1800MHz band in 2012; and between CMHK and HKT in the 2600MHz band in 2016.

- Several forms of network sharing, including network capacity leasing, are currently allowed. For RAN sharing, MNOs may choose to have shared use of all or part of the RAN equipment and facilities including base stations, radio network controllers and backhaul transmission equipment. For legitimate RAN-sharing scenarios in Hong Kong, each participating MNO will maintain its own separate logical RAN using its own assigned spectrum even if it shares the use of the same RAN equipment and facilities with others – there should not be any pooling of spectrum by the participating spectrum assignees. Under the network capacity leasing arrangements, an MNO or MVNO may lease the radio access capacity from other MNOs to expand its service coverage for an area or enhance its network capacity for its own subscribers. With the advancement of carrier aggregation technology, an MNO may also lease another MNO's radio access capacity and aggregate that capacity with its own to enable the provision of higher-speed mobile data services to its subscribers, provided that each MNO will continue to operate its own separate logical RAN using its assigned spectrum.

- Withdrawal of spectrum assignments is possible but would be exercised only in exceptional circumstances and following due process – e.g. if there is demonstrable evidence that the licensee is not making efficient use of frequencies, if a serious breach of licensing conditions has occurred, if serious interference issues are occurring, or in other exceptional circumstances (e.g. withdrawal of frequency is in public interest or due to the government's international obligations).

6.2.2 Demand and supply for spectrum

Based on the industry interviews we conducted, we found that additional mobile spectrum to be in high demand with operators. According to operators, additional spectrum would support the Hong Kong market's incessant demand for mobile data services and would also help operators prepare for the launch of 5G services.

In Hong Kong, most common sub-3GHz spectrum bands identified by the ITU for IMT has already been released, except for the 2.6GHz (2570–2620MHz) TDD band and the 700MHz band (698–806MHz). The released sub-3GHz spectrum is generally well utilised in the Hong Kong market as MNOs have great impetus to fully utilise their available spectrum during the finite term of assignment to support network capacity requirements from their subscribers.

We expect demands for additional spectrum in the sub-3GHz bands to be sustained, while the supply of additional spectrum in the same bands is expected to remain constrained.

The CA has developed a work plan to make available additional spectrum for public mobile services from 2019 that covers spectrum in the 3.4–3.6GHz band ('the 3.5GHz band'), the 24.25–27.5GHz band ('the 26GHz band') and the 27.5–28.35GHz band ('the 28GHz band'). The CA will decide on the assignment arrangements considering views of the industry and interested parties following public consultation.

6.2.3 Demand and supply for spectrum trading

As there is high demand for mobile spectrum by industry stakeholders, it can be expected that some of the industry's demand for spectrum may translate to potential demand for spectrum trading.

Spectrum utilisation in Hong Kong is currently generally high and MNO market shares remain relatively stable. There is no indication of significant changes in market share that will result in an operator having significantly less usage requirements. Notably, the supply of available spectrum in the sub-3GHz bands in the primary market would remain constrained in the short term. If all operators are facing a constraint, it is unlikely that spectrum holders would be willing to sell their spectrum resources in the secondary market. Therefore, the potential supply of spectrum in the secondary market remains in question.

The overall demand for spectrum trading may also be affected by the on-going spectrum auctions conducted to release new spectrum for mobile services. MNOs or other interested parties may wait for the release of new spectrum and acquire it for a full 15 years' term, rather than negotiating with the incumbents to trade the assigned spectrum (which involves additional transaction cost) for the remaining duration of the assignment period.

Given the above, in a spectrum trading regime, the level of trading activity is anticipated to be low in the short term, as would be the benefits so derived.

In addition, most operators interviewed did not express clear intentions to participate in the secondary market for spectrum. One operator heavily supported the introduction of a spectrum trading regime. However, other operators were less keen, stating fears of increased risks due to anti-competitive activities.

6.3 Benefits and costs of introducing a spectrum trading regime in Hong Kong

We have assessed the costs and benefits of introducing trading in Hong Kong, both in the short term (five years) and the medium term (five to ten years).

In terms of overall benefits, Hong Kong does not have regional licensing or perpetual licensing terms. Certain spectrum trading benefits which could be realised under those circumstances will therefore not be applicable to Hong Kong, for example, the ability to aggregate regional spectrum holdings and/or to adapt spectrum use under a perpetual licensing regime.

One of the major benefits of spectrum trading is that, if an MNO does not have enough capacity to meet its short-term need, it may acquire the spectrum from the market through commercial deals with other MNOs. However, in Hong Kong, MNOs can implement certain types of mobile network sharing, such as antenna sharing, site sharing, RAN sharing and capacity leasing through commercial arrangement with other MNOs, which can serve as effective alternatives to resolve MNOs' short-term need for additional capacity. For longer-term need for spectrum capacity, MNOs can bid for additional spectrum by taking part in the auctions to be conducted by the CA regularly when new spectrum becomes available, or when assigned spectrum is returned to the CA upon expiry of term for re-assignments.

The focus of this study is on spectrum with competing demands and spectrum that has (generally) been assigned through market means, i.e. spectrum for public mobile telecoms services. Trade volumes for such spectrum are low even in Category 1 markets that have a clear spectrum trading regime, other than in relation to trading regional licences. Trade volumes are likely to be low in Hong Kong if spectrum trading is introduced, and the benefits of introducing such a regime are unlikely to be substantial compared to the cost of setting up such a mechanism.

In terms of costs and risks, feedback from several industry stakeholders also suggests that costs related to spectrum hoarding and over-concentration of spectrum should be taken seriously. Industry stakeholders also mentioned the potential difficulties in the treatment of potential windfall profits/losses from spectrum already in the market. Although potential costs because of loss of harmonisation, and increased risk of interference were not highlighted in the industry interviews, they are nonetheless important from a regulatory perspective. There may be amendments required to adapt existing safeguards to a formal spectrum trading regime, and further assessment is therefore warranted.

6.3.1 Short-term assessment

In the short term (five years), the introduction of spectrum trading in Hong Kong appears to be a balancing act among (a) the introduction of more flexibility to the overall spectrum assignment regime in terms of permitting asymmetric trades (including partial trades of spectrum holdings) and increased time flexibility in determining when to acquire or relinquish spectrum, (b) costs and potential risks associated with spectrum trading, and (c) safeguards and further regulatory controls required to forestall/alleviate such costs and risks and the related implementation costs.

Our analysis suggests there are no critical bottlenecks in the Hong Kong market that would require spectrum trading as a remedy in the short term (five years). This is because the current spectrum management framework for public mobile telecoms services appears to be reasonably effective in promoting the efficient use of spectrum under existing regulatory mechanisms (e.g. assignment/re-assignment opportunity at regular intervals, capacity leasing mechanism). We also note that as spectrum for public mobile telecoms services is relatively well utilised in Hong Kong, the supply of mobile spectrum for trading and thus level of trading activity is anticipated to be low in the short term and so would be the benefits so derived.

The implementation timeline required to set up the spectrum trading regime is an important consideration in the short term. Considering the experience of other jurisdictions that have dedicated a significant amount of time and effort to set up spectrum trading regimes, as well as the availability of existing regulatory mechanisms (including assignment/re-assignment opportunities at forthcoming auctions), the limited benefits expected in the short term in Hong Kong may not justify the associated costs for introducing and implementing such a regime. Against these considerations, the Government of Hong Kong will have to carefully consider whether it is worthwhile to set up a trading mechanism in the short term.

6.3.2 Medium-term assessment

In the medium term (five to ten years), mobile spectrum usage and development is expected to evolve further. 5G is expected to be the main driver for mobile spectrum usage and development. However, 5G standards are still evolving and the use cases are still not entirely clear. It is likely that 5G will involve more than enhanced mobile broadband and includes use cases for 'massive connections' (IoT), ultra-reliable networks and 5G fixed-wireless access. The different possible use cases for 5G have differing implications on how mobile networks might need to evolve. Spectrum use is likely to become more complex, to the extent that it may be quite different from that of today.

There is a possibility that the additional flexibility brought about by spectrum trading would be useful to cope with 5G development and roll-out. However, we note that current mechanisms already provide flexibility to allow use of existing mobile spectrum to evolve with the needs of 5G (e.g. re-farming of technology-neutral spectrum holdings for future 5G technologies). The expiry of existing spectrum assignments within the next ten years also provides opportunities for the CA to re-organise the band plans if necessary.

Also, it is likely that the supply of 5G spectrum in the frequency range 24.25–86GHz would be large, given that a total of 33.25GHz of spectrum is under study by the ITU for IMT. Although demand is still uncertain at this stage, should it be the view of the CA that there are no competing demands for 5G spectrum in the primary assignment, pursuant to the Radio Spectrum Policy Framework, this spectrum may be assigned administratively instead of through auction. In such a scenario, spectrum trading is not relevant.

Potential 5G spectrum-related challenges are likely to be complex and interlinked, involving shared spectrum usage between different services, and a combination of licensed and licence-exempt

spectrum access. While there has yet to be a clear case for implementing spectrum trading in Hong Kong in the medium term, the CA should monitor the technology and market developments as well as the allocation of mobile spectrum for 5G by the future WRC, and the implications on the spectrum assignment regime for mobile services both in primary and potentially in secondary assignments, with a view to keeping it up to date in the 5G era.

6.4 Proposed approach to spectrum trading implementation if pursued, and alternative methods to enhance the spectrum efficiency in Hong Kong if not pursued

Spectrum trading may be a useful tool to enhance spectrum flexibility and efficiency, but it is not the only solution. There are also other spectrum management tools that can be used. The other tools could also potentially be enhanced to achieve similar benefits to the introduction of spectrum trading, namely facilitating more efficient use of spectrum. We consider both approaches in our summary below.

6.4.1 Recommendations for Hong Kong to implement spectrum trading

Our recommendations on how a spectrum trading regime could be introduced, assuming a trading regime is to be pursued in Hong Kong, are summarised below:

- **Scope for spectrum trading regime to enhance spectrum efficiency**: Only spectrum assigned via market-based methods should be permitted, with no restriction on the types of transaction permitted. Beyond general restrictions on the eligibility of bidders at primary assignments, no additional restrictions should be introduced on the party eligible to trade. All rights and obligations that apply to frequencies being transferred should also be transferred to the buyer in any outright spectrum trade and there should be no change to the overall set of rights and obligations.

- **Proposed process for spectrum trading regime**: All prospective trades shall be reviewed on a case-by-case basis, using a two-tier approval process. This will allow each trade to be considered on its relevant technical merits.

- **Key implementation considerations**: The key principle is to build on the existing regulations and practices adopted by the government to minimise implementation complications resulting from inconsistencies with the existing spectrum management framework.

- **Safeguards for spectrum trading issues**: The two-tier approval process, which includes a competitive assessment, is a key safeguard to prevent trades that may have effect on foreclosure of competition. Other pre-existing safeguards in Hong Kong (i.e. network and service roll-out requirements) can also help to safeguard against other costs arising from the introduction of spectrum trading.

Of note is that safeguards may not be effective in eliminating all potential costs/risks. This is particularly evident for the risk of windfall gains and other private profits to be gained by trading

parties. Regulatory review of trades may remove some of the risk associated with operators profiting but will not comprehensively resolve the issue as approved trades can still be conceived as 'unfairly benefiting' trading parties. As such, there is yet to be a satisfactory solution for these issues.

6.4.2 Alternative mechanisms to enhance spectrum use in Hong Kong, without implementing spectrum trading

Other than spectrum trading, there are other mechanisms that build on the existing system of spectrum management and can be used to create a more flexible environment for spectrum assignment/re-assignment and further enhance spectrum efficiency in the Hong Kong market.

A summary of enhancements to current spectrum management mechanisms without introducing spectrum trading, is as follows:

- **Enhanced mobile network sharing arrangement**: Radio network capacity can be leased to another MNO through a combination of existing RAN-sharing and capacity leasing mechanisms. This will allow the tenant MNO to have more control over how the lessor MNO's spectrum should be deployed. This confers greater timing flexibility to the tenant MNO to increase or decrease network capacity in required areas in response to changing market demands.

- **Periodically adjusted SUF for administratively assigned spectrum**: For administratively assigned mobile spectrum, SUFs can be charged annually and adjusted periodically instead of a fixed fee for the 15-year duration. This allows operators to have greater timing flexibility in determining when to acquire or relinquish spectrum holdings, allowing spectrum users more flexibility to respond to market changes.

- **Enhanced spectrum swap**: The current mechanism can be enhanced to permit inter-band and/or asymmetric bandwidth spectrum swaps, which will improve flexibilities of spectrum use to adapt to changes brought about by technology evolution. Asymmetric swaps of spectrum will create more options for operators to reorganise their existing spectrum holdings to form spectrum with wider bandwidth, which may contribute to gains in spectral efficiency.

Annex A Case studies of markets in Category 1

This annex reviews how international regulators have implemented a spectrum trading framework, the rationale for the introduction of spectrum trading and the volume of spectrum trades in the market. As part of each case study, we analyse the drivers behind spectrum trading activity and how the framework has facilitated a more efficient usage of spectrum in individual countries, where applicable. The scope of our analysis includes the following five countries: Australia, New Zealand, the UK, the USA and Canada.

A.1 Australia

The Australia Communications and Media Authority (ACMA)[61] is responsible for managing and regulating the radiofrequency spectrum and its renewal process in accordance with the Radiocommunications Act 1992.[62]

Rules for spectrum trading have been defined by ACMA and are set out in the Radiocommunications (Trading Rules for Spectrum Licences) Determination, 2012 ('the Determination').[63]

In 2015, ACMA and the Department of Communications and the Arts issued a report setting out proposals for changes to how spectrum is managed in Australia (and for the evolution to more advanced market-based approaches), in response to a call for reform proposed by the Australian Government.[64] New legislation (replacing the Radiocommunications Act 1992) is under consideration, giving the ACMA new powers to manage spectrum in future to meet rapidly evolving changes in market demand and to respond to the latest developments in wireless technology, including trends towards a more dynamic operation of wireless systems.

A.1.1 Background on spectrum trading

Before the reforms of the 1990s, all spectrum licences in Australia were assigned and reassigned through administrative means. In the Radiocommunications Act 1992, market-based spectrum licensing, including spectrum auctions and tradable licences, was introduced to specified spectrum bands alongside the administrative system.

---

61 Previously, the Australian Communications Authority (ACA).

62 https://www.legislation.gov.au/Details/C2017C00356.

63 https://www.legislation.gov.au/Details/F2012L01718.

64 Australian Government, Department of Communications and the Arts (2015), *Spectrum Review*. Available at https://www.communications.gov.au/publications/spectrum-review-report.

Primary awards of spectrum – current

Currently, ACMA adopts two methods of licensing spectrum to users, in addition to class licences, which are open to be used by any person on a shared and unlicensed basis.

- **Apparatus licences** – These licences are granted to a user to operate specific devices in a defined portion of the spectrum. They are site-, service- and technology-specific and are processed administratively for a fixed fee. Most apparatus licences are issued for a renewable one-year tenure but can be issued for up to five years, with some scope for renewal.

- **Spectrum licences** – These licences permit the operation of devices within a defined geographical area and frequency band, subject to conditions and the technical framework established by ACMA for the band. Spectrum licences are technology neutral, enabling spectrum users to use a broad range of technologies, and allowing them to migrate to newer technologies without regulatory intervention.

Spectrum licences are issued using a price-based method, through auction, tender or pre-determined or pre-negotiated price, for a period of up to 15 years. Primarily, ACMA allocates spectrum licences by auction as it views this approach as "*the simplest and most transparent method of allocating resources where there is competing demand*".[65]

Spectrum licences are issued by ACMA at a minimum of one standard trading unit (STU). STUs are commodity blocks of spectrum, and is also the minimum unit of space for which ACMA will allow trading. The frequency bandwidth component of an STU is 1Hz. STUs are finite and indivisible and are defined by geographical area and radio frequency bandwidth. This allows stacking of multiple STUs horizontally to enable greater coverage, or vertically to provide greater bandwidth. ACMA has divided spectrum into regional lots at recent auctions, covering urban and sub-urban Australia.

There has been a gradual shift towards converting spectrum bands previously awarded using apparatus licencing into 15-year market-based spectrum licences to maximise the overall benefit derived from the spectrum and to provide certainty for the licence holders of the band.[66]

In cases where spectrum licences have been deemed as being under-utilised by the current licence holders (i.e. 27GHz and 28GHz bands), ACMA has also taken to reverting these licences from spectrum licencing to site-specific apparatus licensing to enable the provision of additional services within the spectrum, while ensuring continuity of service delivery for existing licensees.

---

65 Source: ACMA website, Spectrum licensing FAQs.

66 E.g. Apparatus licences in the 1800MHz band and the 2570–2620MHz mid-gap band were not renewed and converted to spectrum licences at 1800MHz and 2.5GHz auctions, respectively.

Primary awards of spectrum – proposed

In May 2017, the Department of Communications and the Arts released the *Exposure Draft of the Radiocommunications Bill 2017*, which proposes a revised spectrum management framework and is under consultation until 30 June 2017.[67] The Bill, if enacted, will trigger a move towards a single licensing system, aiming to address inflexibilities of the current legislation. Specifically, ACMA anticipates the new framework to incorporate the following principles:[68]

- Removal of legislative barriers between spectrum and apparatus licences, allowing ACMA to design licences that would have the characteristics of either or both current licence types.
- Introduction of new mechanisms for treatment of licences, including licence conditions and 'designated statements', which would dictate the protocol in terms of such issues as renewal, subdivision and third-party authorisation.
- Use of spectrum authorisations, rather than licences, to authorise use of devices in a part of the spectrum by a group of spectrum users without an application process; this is to be analogous to the class licences currently in place.

Introduction of spectrum trading

Spectrum trading was introduced in Australia via the Radiocommunications Act 1992, which allows a licensee to assign part or all of their licences to another party, compliant to ACMA's Determination.[69] Both apparatus licences and spectrum licences can be traded between parties. Spectrum trading is understood to have been introduced in adherence with the general objectives of the Act: maximising public benefit through efficient allocation and use of spectrum and providing a responsive and flexible approach to addressing the needs of spectrum users.[70]

As part of the reform, spectrum licences could be broken down into specific geographies and bandwidths based on STUs. As such, spectrum trading became an important tool to facilitate operators to consolidate or divest their spectrum interests within a specific region after the primary assignment. ACMA defines a minimum contiguous bandwidth (MCB) for every spectrum licence band that is between 1–50MHz;[71] this corresponds to 1–50 STUs. Trading may be restricted if the spectrum holdings of the initial owner and the receiving party does not meet the MCB. This is to prevent spectrum licences to be split into impractical sizes, thus helping to alleviate unnecessary

---

67 Department of Communications and the Arts (2017), *Exposure Draft of the Radiocommunications Bill*. Available at https://www.communications.gov.au/what-we-do/spectrum/spectrum-reform.

68 ACMA (2017), *The licensing system: Supporting material for the Exposure Draft of the Radiocommunications Bill 2017*. Available at https://www.communications.gov.au/file/27086/download?token=cDCylaPP.

69 https://www.legislation.gov.au/Details/F2012L01718.

70 Source: ACMA, October 2013, Object and scope of the Radiocommunications Act 1992.

71 Every spectrum licence band has a defined MCB which is specified in the Radiocommunications (Trading Rules for Spectrum Licences) Determination 2012.

administrative cost and inefficiency in spectrum use. By restricting the MCB, ACMA also prescribes the maximum number of frequency boundaries (and thus the maximum number of operators) that are permitted within the spectrum.

However, since the implementation of the reforms, trading activity remained low and establishment of a trade generally would take a long time.[72] This is due to the inconsistency in the STUs' sizes and conditions as well as the expensive stamp duties on spectrum trades.

To facilitate greater flexibility in the quantum of spectrum that may be traded, ACMA amended the Determination in 2012 to standardise the adoption cells of the Australian spectrum map grid 2012 (the 2012 ASMG)[73] as the geographical component of the STU. This consistency simplifies the trading of spectrum between licensees and provides greater granularity across the whole of Australia. Previously, spectrum in outback and rural areas was defined in larger cell sizes, making it difficult to administer spectrum trading.

There have also been consultations on the removal of stamp duties, which are seen to have impeded secondary trading of spectrum licences.[74] In response to the review of spectrum trading conducted in 2008, ACMA noted that stamp duties on spectrum trades should be removed by 01 July 2013. However, this has not happened across all States and Territories. As of March 2017, some jurisdictions (e.g. Queensland, Northern Territories) are yet to abolish stamp duty on the trading of spectrum and apparatus licences.[75] Historically, stamp duty has been levied on a tiered basis and ranged between 1.5–5.75%, with variations across States and Territories.

Additionally, the Australian government is also considering to replace the current legislation with one that would "*provide for greater market-based activity, including increasing the opportunity for spectrum holders to share and trade spectrum*".[76] Recommendations from a spectrum review conducted in 2015 propose, inter alia, establishing a single licensing system and homogenising the duration of spectrum licences, making it easier and more flexible for spectrum to be allocated and reallocated (through trades). Implementation of the recommendations is in progress.

---

72 Source: ACMA (2008), *Spectrum Trading: Consultation on trading and third-party authorisations of spectrum and apparatus licences*.

73 The cells of the 2012 ASMG are mapped consistently in five-minute (5') increments (approximately 9×9km), by latitude and longitude.

74 Source: ACMA (2008), *Spectrum Trading: Consultation on trading and third-party authorisations of spectrum and apparatus licences*.

75 Source: AMTA (2017), *Submission to Australian Communications and Media Authority for Reconfiguring the 890–915/935–960MHz Band*. Available at https://www.acma.gov.au/theACMA/reconfiguring-the-890-915-935-960-mhz-band.

76 Source: Department of Communications and the Arts, and ACMA (2015), *Spectrum Review*. See https://www.communications.gov.au/what-we-do/spectrum/spectrum-review.

A.1.2 Implementation of spectrum trading

Scope of spectrum eligible for trading

Both spectrum licences and apparatus licences can be traded / transferred.

The following table provides the spectrum band for which spectrum licences have been issued.

Figure A.1: Assignment of spectrum licences in Australia [Source: ACMA, 2017]

Spectrum band	Frequency range	Allocation	Remarks
700MHz	694–820MHz	Mobile, fixed	Regional use
800MHz	820–890MHz	Mobile, fixed	Regional use
1800MHz	1710–1880MHz	Mobile, fixed	Regional use
2GHz	1990–2170MHz	Mobile, fixed	Regional use
2.3GHz	2302–2400MHz	Mobile, fixed	Regional use
2.5GHz	2500–2570MHz 2620–2690MHz	Mobile, fixed	Regional use
2.5GHz Mid-band	2570–2620MHz	Mobile, fixed, broadcasting	Currently unallocated
3.4GHz	3.42–3.57GHz	Mobile, fixed	Regional use
20/30GHz	20.20–21.20GHz 30.00–31.00GHz	Defence[77]	National use

Other licensable spectrum falls under the purview of the apparatus licences framework, including aeronautical, aircraft, maritime, space, land mobile and fixed point-to-point applications.

ACMA is currently monitoring the development of 5G and is working with industry to examine the adequacy of current spectrum arranges for 5G and the Internet of Things (IoT).[78] These include consideration of higher-frequency bands that have also been identified by the Federal Communications Commission (FCC) in the USA for 5G (i.e. 27.5–28.35GHz, 37–40GHz and 64–71GHz bands). The detailed licencing framework for 5G has yet to be developed.

77 Based on *Radiocommunications (Trading Rules for Defence Spectrum Licences) Determination 2015*.

78 Source: ACMA (2016), *Five-year spectrum outlook 2016–20*. This paper also notes that there has been greater interest in Australia to use lower-frequency bands – 2.3, 2.5, 3.5 and 3.6GHz bands for 5G. See https://www.acma.gov.au/theACMA/five-year-spectrum-outlook-2016-20

Forms of spectrum trading

Spectrum licences are fully tradeable and can be aggregated, divided or re-assigned to third parties, subject to compliance with the interference-management framework established by ACMA.

Ownership of an STU cannot be shared, but licensees may subdivide their spectrum holdings, based on geographical area, bandwidth or both, into the component STUs and sell them subject to meeting the minimum contiguous bandwidth specified by ACMA.[79]

Additionally, spectrum licence holders may lease spectrum, either through exclusive use or by spectrum-sharing arrangements. The term of lease can be less than the length of the original spectrum licence, after which the rights of use will return to the original licence holder. Records of third-party licences must be held by the licensees. Apparatus licences can be transferred to third parties based on the provisions of Section 131AA of the Radiocommunications Act 1992. They are less frequently traded due to the relatively short licence period (maximum of five years). The licences also do not have guaranteed renewal and are subject to annual licence fees. Apparatus licences can be leased to third parties.

Spectrum liberalisation (extent of technology and service-neutral spectrum)

Spectrum licences are a tradable, technology- and service-neutral (i.e. not related to any technology, system or service) spectrum access right for a fixed non-renewable term of 15 years.

Within the bounds of spectrum space (geographical area and frequency band) and the technical interference-management framework, licensees are free to operate whatever type of communications service they choose. Licensees can change their usage in response to technical improvements or changes in consumer demand. This flexibility is conditional on ACMA's technical approval of some types of device.[80]

Apparatus licences are granted on a service- and technology-specific basis. Thus, they do not confer change-of-use benefits.

Interference management

Emission limits are set at frequency boundaries to limit interference for bands under the spectrum-licencing framework. Licensees must register their devices and self-certify that they will not cause unacceptable interference. In addition, STUs limit the number of technologies operated in the band, thereby reducing non-linear interference such as intermodulation.

---

79 MCBs range from 1MHz to 50MHz depending on the frequency band.

80 Source: ACMA website, Spectrum licensing FAQs.

Process for completing spectrum trades

Licence trades may be negotiated directly via bilateral agreements or indirectly via a broker, typically specialised consultancies. Price is subject to negotiation, but licence conditions cannot be altered without recourse to ACMA. Most licences traded have changed hands via bilateral agreements, with a few others by brokered negotiations. Several specialised consultancies have assumed some of the role of facilitating spectrum trades (e.g. Market Dynamics[81] and Futurepace RF Solutions).[82]

There is no ex-ante regulatory clearance required from ACMA before proceeding with the trade. Both parties are only required to notify ACMA on the spectrum traded or leased after agreement has been obtained. The trade would become effective when ACMA has officially included it in the radiocommunications licence register, typically within one week of notification.

Regulatory measures related to spectrum trading

Competition concerns regarding spectrum holdings are within the remit of ACMA, but general competition law applies. The Trade Practices Act enables the Australian Competition and Consumer Commission (ACCC) to action against licensees where there is evidence of spectrum hoarding for anti-competitive reasons, such as to block a competitor from accessing spectrum. No significant concerns have been raised to date.

Spectrum band caps (also called 'allocation limits' by ACMA) have been imposed on spectrum bands at some auctions to restrict operators from holding too much spectrum. For instance, at the digital dividend auction in 2013, a limit of 2×20MHz was placed in the 700MHz band nationwide and a limit of 2×40MHz was placed in the 2.5GHz band nationwide. Allocation limits have been considered but not imposed by ACMA at recent auctions.

Provision of information on spectrum and spectrum trading

A searchable public online register, with a graphical presentation of licence numbers and geographical areas for all spectrum licences issued via auction or conversion,[83] is maintained by ACMA to reduce information costs and to facilitate trading. However, information on confidential users is withheld. There is no register of spectrum trading available.

ACMA also collects pricing information on a voluntary basis and is in discussion on the approach to publish the price data while respecting the confidentiality of traders.

---

81 http://www.market-dynamics.com.au/.

82 http://www.futurepace.com.au/.

83 Source: ACMA website: "*A conversion is where existing apparatus licence incumbents in the band are offered a spectrum licence for a pre-determined price to replace their existing apparatus licences.*"

A.1.3 Volume of spectrum trading activity

ACMA does not provide statistics on trading activity of spectrum licences. However, it has noted in its *Spectrum Review of 2015* that "*market-based activity, specifically trading or leasing of spectrum – which available, is not being made use of extensively*".[84] The cited reasons for this are lack of certainty on licence tenure as well as a complicated and lengthy licensing system.

However, there is one notable trade on the secondary market in Australia in recent years due to the sub-optimal use of 2.5 and 3.5GHz spectrum. In 2011, NBN Co[85] spent AUD120 million buying 2.5 and 3.5GHz spectrum licences owned by telecoms company Austar (which was subsequently acquired by Foxtel in 2012) for fixed–wireless services to 4% of the population.[86] The asset sale would allow NBN Co to roll out a high-speed fixed–wireless service to rural and regional areas using LTE-TDD technology, thereby making use of the underutilised 2.5GHz and 3.5GHz spectrum. Austar initially acquired the wireless spectrum with the intention of rolling out a regional wireless broadband network in metropolitan areas based on WiMAX technology. However, the plans were cancelled, and Austar sought to sell its spectrum holdings since. It has previously entered into an agreement to sell its spectrum licences to the OPEL consortium (Optus & Elders) for AUD65 million and enter a wholesale agreement with Optus for the resale of products operated by the OPEL consortium. However, the deal fell through when OPEL's WiMAX based network roll-out was cancelled by the government.

Information on apparatus licence transfers is not available.

A.2 New Zealand

Radio Spectrum Management (RSM), a business unit within the purview of the Ministry of Business, Innovation and Employment (MBIE),[87] is responsible for enforcing spectrum policy and spectrum management in New Zealand in accordance with the Radiocommunications Act 1989.

In addition, the Telecommunications Act 2001 establishes the obligations applicable to providers of telecoms services in New Zealand, and the appointment of a Telecommunications Commissioner within the Commerce Commission. The Commission is responsible for monitoring competition in New Zealand's telecoms market, and for primary and secondary trading of spectrum.

---

84 ACMA (2015), *Spectrum Review*. Available at https://www.communications.gov.au/what-we-do/spectrum/spectrum-review.

85 NBN co was established in 2009 to design, build and operate Australia's new fast, wholesale local access broadband network.

86 NBN Co will pay AUD58 million for a subsidiary which holds spectrum licences in the 2.3 and 3.4GHz bands, with a further AUD62 million paid for the assignment of the subsidiary's debt. Source: https://www.itnews.com.au/news/nbn-co-buys-austar-wireless-spectrum-for-120m-248454.

87 Previously the Ministry of Economic Development (MED).

A.2.1 Background on spectrum trading

New Zealand was the first country in the world to allow secondary trading of radio spectrum. The Radiocommunications Act 1989 introduced a scheme of tradable spectrum rights. Since 1989, the government has progressively transferred more frequencies to the market-based framework by creating Management Rights for more frequency bands. As of April 2017, there were 77 Management Rights, of which the government retained 11.

Primary awards of spectrum

Spectrum in New Zealand is assigned using two main approaches:

- **Radio Licence Regime** (RLR) – Under this regime, radio licences are typically specific to transmitter, type of equipment and transmission methods, and are assigned via an administrative assignment process. Radio licences are mainly used for applications in the public interest, and assignment is evaluated annually.

- **Management Rights Regime** (MRR) – This regime is largely applicable to nationwide spectrum used primarily for commercial purposes (e.g. public mobile services and broadcasting services).

MRR was introduced through the Radiocommunications Act of 1989, enacted through deregulation of the telecoms and broadcasting industries. There are two levels of rights under MRR:

- Management rights are long-term leases[88] that give the manager the exclusive right to manage a nationwide band of frequencies. The government can either retain the Management Right of a band (usually for social defence and/or security obligations) or allocate a tradable Management Right to a private entity. Within this band, the manager can issue spectrum licences.

- Spectrum licences give the holder the right to use spectrum within the band specified within a defined geographical area. The range of uses to which spectrum can be put is unlimited, other than by interference constraints.

Subsequently, New Zealand pioneered auctions as the primary mechanism to allocate management rights and spectrum licences, and has favoured using this mechanism for MRR assignment since. Management rights and spectrum licences may be auctioned simultaneously, allowing market participants to determine whether one user controls both management and usage rights for that band, or whether more than one user sits under a band manager. Following the primary assignment, both management rights and spectrum licences (usage rights) can be traded freely. Unless specified in licence conditions, there are no restrictions on the activities of operators or on the number of entrants into the market.

88 The Radiocommunications Act 1989 follows for allocation of spectrum rights for a period of up to 20 years.

In 2003, the Ministry of Economic Development (MED) started to consider the practical issues surrounding the fixed tenure of management rights. Following a lengthy debate and public consultation, the government decided that, five years before a management right is due to expire, the existing rights holder will be offered a replacement spectrum right at a price that reflects its current market value subject to a case-by-case assessment. If existing rights holders do not wish to renew at this price, the respective rights will be reallocated by way of an auction. The government also reserves the right to deny right of renewal of certain spectrum should it be deemed as necessary after renewal assessment.[89]

Management rights and their underlying spectrum licences (usage rights) are offered in primary auctions on a nationwide basis. There has been discussion on offering rights at a local and regional level to lower the barriers to entry for new entrants seeking to offer telecoms services. In 2009, Managed Spectrum Park (MSP) was established in 2009 to cater to the scenario "*in which a nationwide spectrum right is not required, but likewise a general user licence would be too open as services require some coordination or sharing. It is intended for local and regional services, and seeks to encourage a flexible, cooperative, low cost and self-managed approach to allocation and use*".[90] MSPs are technology-neutral and have a six-year term with a right to renewal on certain conditions. 'Use-or-lose' provisions also apply.

An example is the 2.5GHz MSP which consists of spectrum from 2575–2620MHz for wireless broadband applications, where licences are allocated on a 'first-come, first-served' basis. To reduce the first mover's advantage, there are arbitration provisions to encourage spectrum sharing, so that the privilege does not solely belong to a single operator. New applicants for MSP licences would need to certify that their new service will not cause harmful interference to existing services before RSM grants an MSP licence. In the case where the new service will affect other licensees, parties involved can negotiate spectrum-sharing mechanisms and involve an arbitrator if required.

Introduction of spectrum trading

New Zealand was the first country in the world to allow secondary trading of radio spectrum together with the auctioning of private spectrum rights as part of deregulation of the telecoms sector.

---

89 For example, a paper published by the Cabinet Economic Development Committee on the arrangements for the renewal of radio spectrum management rights used for cellular services in the 800 and 900MHz bands proposed that freeing up 7.5MHz in each band to the open market would strike the best balance between providing certainty for incumbents and making the mobile market more attractive to new entrants. The paper is available at https://www.rsm.govt.nz/projects-auctions/pdf-and-documents-library/recently-completed-projects/expiry-of-spectrum-rights-2013-implementation/renewal-of-800-900-cellular-rights/renewal-of-800-900-cellular-services-cabinet-paper.

90 Source: MBIE website. MSPs are technology-neutral and have a six-year term with a right to renewal on certain conditions. 'Use-or-lose' provisions apply.

This was to allow management rights to be traded freely following the primary assignment and to allow "*rightholders a high degree of choice in levels and timing of investment*".[91]

However, the use of secondary trading remained constrained. The MED contended that the reason for this was due to New Zealand's small consumer market, high entry costs of telecoms services, limited number of buyers and sellers and the ready availability of inexpensive alternative spectrum under the RLR, which decreases operator's incentive to trade.[91]

A.2.2 Implementation of spectrum trading

Scope of spectrum eligible for trading

All spectrum under MRR can be traded. The following table depicts the spectrum under MRR and the specified frequency allocations.

Figure A.2: Spectrum under MRR [Source: Ministry of Business, Innovation and Employment, 2017]

Frequency band	Frequency range	Allocation
Medium frequency	521–1612kHz	Broadcasting
Very-high frequency	44–50MHz	Mobile, fixed (currently unallocated), short-range devices
	54–68MHz	Mobile, fixed
	87–108MHz	Mobile, broadcasting, fixed
Ultra-high frequency	502–694MHz	Broadcasting
	694–806MHz	Mobile
	825–960MHz 1710–1980MHz 2010–2170MHz 2200–2395MHz 2500–2690MHz	Mobile, fixed
Super-high frequency	3.40–3.60GHz 24.55–25.40GHz	Mobile, fixed
	25.50–27.00GHz	Mobile, fixed, space research
	27.00–28.35GHz	Mobile, fixed, satellite communications

Forms of spectrum trading

New Zealand's liberal trading regime allows for all spectrum managed under MRR to be traded. In detail, the Radiocommunications Act 1989 permitted the following:

91 Source: MED (2005), *Review of Radio Spectrum Policy in New Zealand*. Available at http://www.itu.int/osg/spu/stn/spectrum/spectrum_resources/general_resources/report_NewZealand.pdf.

- sale/ transfer of management rights from one manager to another, whole or in part (Part 5)
- aggregation of management rights from one manager to another (Part 5)
- assignment of spectrum licences under management rights, full term or leasing (Part 6)
- mortgage of management rights by managers (Part 9).

As right managers are conferred the power to create spectrum licences in accordance with Part 6 of the Radiocommunications Act 1989, multiple spectrum licences can exist within a management right. Spectrum licences can also be created to permit spectrum sharing under the MRR.

Spectrum licensees (the right holders) are also allowed to transfer their rights to another party without consent of their managers if their licence right permits.

Spectrum liberalisation (extent of technology and service-neutral spectrum)

Generally, licences issued by RSM are service-specific (i.e. mobile, fixed or broadcasting services) and do not typically come with conditions specifying the technology that may be used.

Before management rights can be auctioned, a consultation process on lot design is conducted to define the assignment of spectrum, configuration of lots, size of each management right, boundary conditions, and whether rights should be issued as paired or unpaired bands. This process effectively restricts the usage spectrum to a service. It might also prescribe the technology that can be used, i.e. if assignment for mobile usage is designed in paired blocks, it would be more suited for frequency division duplexing (FDD) equipment rather than time division duplexing (TDD).

RSM then conducts a review on a case-by-case basis when management rights are renewed (typically five years before the expiry of a licence under MRR) to consider whether the configuration of the rights promotes highest-value use, or whether adjustments are warranted. In cases where technology trends have shifted greatly since the spectrum was allocated (and before spectrum is due to be reviewed), RSM would assess if it should allow modification of licence conditions to favour another technology. For example, in the 3.5GHz band, after a public consultation conducted in 2015, RSM allowed licensees to modify their existing licences to incorporate greater use of TDD equipment if they wished. The 3.5GHz band, expiring in 2022, was initially not due to be reviewed until 2017.

Exceptions to single-type-of-use stipulations also arise when there is a potential for higher-value usage, but the technology involved is still nascent. In this case, specific lots could be reserved in anticipation of this future use. For example, in the December 2007 auction of spectrum in 2.3GHz and 2.5GHz bands, specific provision was made for two sets of paired lots to be reserved for next-generation cellular terminals if it is deemed to have higher value than WiMAX use, while other lots provided only for WiMAX use.

Interference management

Spectrum licences have unwanted emission limits and maximum permitted interference limits; thus, interference management is the responsibility of spectrum licensees. Management rights holders are not responsible for ensuring that their spectrum holders comply with the interference limits.[92]

Process for completing spectrum trades

In general, no specific legislation requires ex-ante regulatory clearance for all spectrum trades. However, the regulator could place restrictions on certain management rights (as part of licensing conditions of the spectrum auctioned), which call for prior written consent of the Chief Executive of the MBIE before the spectrum can be traded.[93]

After bilateral agreements are reached, spectrum licences are transferred by presenting a Form 9 (notice of transfer of spectrum licence) instrument to the Registrar of Radio Frequencies. The transfer is complete when the Registrar registers the licence transfer. Mortgages of management rights or spectrum licences also require presentation of a memorandum of mortgage to the Registrar of Radio Frequencies.

Regulatory measures related to spectrum trading

There are no sector-specific competition rules. Instead, such concerns within the industry are dealt with using New Zealand's generic competition legislation.

The Radiocommunications Act deems management rights and spectrum licences to be assets of a business for the purposes of Section 47 of the Commerce Act 2001, which prohibits the acquisition of assets (in this case management rights and spectrum licences) if the acquisition has the effect of substantially lessening competition in a market.

On concerns of spectrum hoarding, regulators have considered both spectrum caps[94] and 'use-or-lose'[95] legislation during the 1994 review of the Radiocommunications Act. At the time, the

---

92 Source: Radiocommunications Agency (2002), *Experience of spectrum trading in Australia and New Zealand*.

93 For example, in the 700MHz auction. Source: MBIE (2013), *Draft 700MHz Management Rights Agreement*. Available at https://www.rsm.govt.nz/projects-auctions/pdf-and-documents-library/recently-completed-projects/digital-switchover-and-the-digital-dividend/700-mhz-auction/700%20MHz%20Auction%20Management%20Rights%20Agreement%20-%20draft%2027%20September%202013.pdf.

94 Spectrum caps are generally placed on spectrum ownership, rather than spectrum usage. Thus, leasing will not fall under the cap.

95 A 'use-or-lose' condition is applied when there are implementation or coverage requirements by a certain date for the spectrum.

Ministry did not consider the characteristics of radiocommunications (and by extension spectrum) to warrant individual legislation beyond the Commerce Act.[96]

However, since 2000, spectrum caps have been levied on individual management rights (i.e. in-band spectrum caps) during public auctions. The caps are defined on a case-by-case basis and can be applied either at original assignment, preventing any one entity from accumulating more than a specified share of spectrum being auctioned or of total spectrum in the industry, or continuously following an auction, blocking any spectrum trading that would result in a similar distribution of spectrum.[97] For example, in the 2.1GHz 3G cellular spectrum that took place in 2001, three-year 2×15MHz spectrum caps were imposed on spectrum management rights. The caps were reviewed and extended in 2004, 2007, 2010 and 2013, with the cap being relaxed to 2×25MHz in 2010 and expiring in 2014. The last cap extension was implemented due to the 700MHz auction taking place between 2013 and 2014, creating market uncertainty around additional spectrum investments.[98] The 700MHz auction also featured three-year caps, which limited spectrum acquisitions to 2×15MHz and are to be revised in 2017.[99]

Additionally, some auctioned lots comprise early management rights, or conditional management rights that cover different time frames within the right validity period. Early management rights are typically issued with implementation and service-requirement covenants to be met before the expiry of the early management rights. Conditional management rights, that last until the original lot expiry date, would only be issued by the government on the condition that covenants in the early management rights have been attained. There are scenarios where buy-out rights have also been issued (e.g. in the 2.3 and 2.5GHz auction). Buy-out rights sit between early management and conditional management rights, and allow the purchaser to extend the date from meeting the implementation requirement but at a price higher than the auctioned value.

Provision of information on spectrum and spectrum trading

The Registrar of Radio Frequencies is available online. Parties interested in trading a spectrum licence or a management right can use the Registrar to establish with certainty the nature of the right and its legal owner. The Registrar also provides for the registration of charges over rights (‘mortgages’) and claims of legal interests in rights (‘caveats’). These provisions apply to spectrum licences only.

96 Source: MBIE, Radiocommunications History in New Zealand.

97 Source: MED (2005), *Review of Radio Spectrum Policy in New Zealand*. Available at http://www.itu.int/osg/spu/stn/spectrum/spectrum_resources/general_resources/report_NewZealand.pdf.

98 Source: MBIE website (September 2015), 2.1GHz 3G cellular spectrum caps reviews.

99 Source: MBIE (2013), *Draft 700MHz Management Rights Agreement*. Available at https://www.rsm.govt.nz/projects-auctions/pdf-and-documents-library/recently-completed-projects/digital-switchover-and-the-digital-dividend/700-mhz-auction/700%20MHz%20Auction%20Management%20Rights%20Agreement%20-%20draft%2027%20September%202013.pdf.

A.2.3 Volume of spectrum trading activity

The volume of spectrum trading in New Zealand has been generally low. Trading activity mainly falls in one of the two following domains:

- Sale of unused spectrum – In March 2016, Spark acquired spectrum management rights for 70MHz of unused spectrum 100 in the 2.3GHz band held by Craig Wireless and Woosh Wireless, for NZD9 million. The additional spectrum allows Spark to expand its fixed–wireless offering through LTE, which has surpassed WiMAX technology as the preferred choice of FWA technology since the 2007 auction.

- *Trade prompted by merger and acquisition activity* – As part of the acquisition of TelstraClear by Vodafone for NZD840 million in 2012, a significant portion of TelstraClear's spectrum holdings was sold to Vodafone, including 2×10MHz of 1800MHz, 2×28MHz of 2.0GHz, 2×10MHz of 2.1GHz FDD, 5MHz of 2.1GHz TDD and 2×21MHz of 3.5GHz. However, due to anti-competition concerns, the Commerce Commission did not permit that all TelstraClear's spectrum holdings be acquired. TelstraClear transferred 2×15MHz of 1800MHz and 2×5MHz of 2100MHz FDD spectrum to another Telstra entity, Telstra Corp. The latter, in turn, sold management rights of 2×15MHz of 1800MHz to 2degrees in February 2013, allowing 2degrees to obtain 25MHz of contiguous paired spectrum in the 1800MHz band, equivalent to that of Vodafone and Telecom.

There is no publicly available information on leases and mortgages.

A.3 UK

The Office of Communications (Ofcom) is the communications regulator in the UK, governing telecoms services and spectrum management in the country.

A.3.1 Background on spectrum trading

Primary awards of spectrum

Ofcom allocates spectrum via two types of mechanisms:

- **Market-based mechanism** – Spectrum rights for public mobile, fixed–wireless, national block licences for fixed links and satellite spectrum are allocated through auctions with indefinite

100 The spectrum was intended by the regulator to provide fixed–wireless access (FWA) services using WiMAX technology, with 'use-it-or-lose-it' regulation set at 31 December 2016. However, the spectrum was left unused after Woosh's failed joint bid with Kordia for the government's Rural Broadband Initiative, with Woosh choosing to deliver FWA services using spectrum over its 2.0 and 2.2GHz band.

licence duration and an initial licence term after which the licence can be revoked at a specified notice;[101] annual licence fees can be levied on the licensees for the use of spectrum

- **Administratively assigned** – All other spectrum, such as that used for fixed services, business radio and private is are administratively assigned.

Introduction of spectrum trading

Spectrum trading was first mentioned in a consultation document published by Ofcom in October 1998 and is understood to have been considered for the following reasons:[102]

- **Benefits to the economy** – Trading allows more spectrum to be "*employed in the use, and by the user, that brings the greatest benefit to the economy*". Trading also provides for the "*opportunity to minimise the transaction costs of acquiring spectrum*" and "*creates a mechanism for entrepreneurs who wish to use spectrum for innovative and high-value new services to acquire spectrum from outdated, declining or low-value technologies*".

- **Benefits to consumers** – Ofcom believes that "*greater flexibility to change the use and configuration of licences, will be strongly beneficial to consumers*". This may arise from cheaper prices since "*providers of [wireless] services may be able to provide extra capacity more cheaply by acquiring rights to use or access additional spectrum*", and greater choice from "*alternative suppliers of popular services… [who can] enter the market by acquiring rights to use spectrum previously used for other purposes" and "faster access to innovation*".

- **Benefits to spectrum users** – Both large and small spectrum users benefit from "*greater certainty over the term of their rights to use spectrum*" and "*the opportunity to improve returns from under-used spectrum resources*". Additionally, spectrum trading can be expected to "*remove barriers to entry to markets where lack of access to spectrum previously restricted entry by new players*".

Spectrum trading was implemented in the UK in December 2004 through Wireless Telegraphy (Spectrum Trading) Regulations. The measures were gradually implemented by licence class since January 2005. Ofcom subsequently completed work to simplify spectrum trading and to enable more flexible trades (e.g. leasing).[103]

---

101 The 2013 800MHz and 2.6GHz licences were awarded indefinitely, with a 20-year initial term, after which the licence can be revoked at a five-year notice.

102 Source: Ofcom (2003), *Spectrum Trading Consultation*. Available at https://www.ofcom.org.uk/__data/assets/pdf_file/0019/41275/pdf_version.pdf.

103 https://www.ofcom.org.uk/consultations-and-statements/category-1/simplify.

A.3.2 Implementation of spectrum trading

Scope of spectrum eligible for trading

The spectrum types that can be transferred[104] are public mobile, fixed–wireless, fixed services, satellite, business radio, maritime, as well as science and technology spectrum. Spectrum leasing is only allowed for public mobile and business radio spectrum.

Although spectrum is assigned on a nationwide basis, it can be broken down by geography for partial transfers.

Forms of spectrum trading

In the UK, spectrum rights owners can transfer, lease and sub-lease spectrum:

- **Transfer/sharing:**
  - *Total transfer* – all rights and obligations under a licence are transferred, and the spectrum buyer holds such rights and obligations exclusively.
  - *Total sharing* – all rights and obligations are transferred, and results in both the seller and buyer holding those rights simultaneously.
  - *Partial transfer* – only some of the rights and obligations (e.g. relating to some geographical areas or some frequencies only) are transferred to the buyer on an exclusive basis.
  - *Partial sharing* – only some of the rights and obligations are transferred to the buyer to hold those rights and obligations simultaneously with the seller.
- **Lease** – The licence benefit is conferred to the leaseholder for a defined period, granting authorisation to use the spectrum. The leaseholder will need to comply with the lessor's licence conditions. At the end of the lease, the spectrum rights return to the original rights holder for the remaining licence term.
- **Sub-lease** – This occurs when a leaseholder leases spectrum to another party. This must be agreed by the lease owner, and only one level of sub-leasing may be permitted. Similar restrictions to those applicable to leasing must apply to sub-leasing, for example the sub-leaseholder must comply with the lessor's licence terms.

104 Ofcom's Trading Guidance Notes, 2015. Note that the type of spectrum trades allowed vary by licence class and band. For example, some spectrum cannot be used for a concurrent trade, while some is restricted by geography for partial trades.

Spectrum liberalisation (extent of technology and service-neutral spectrum)

In the case of a spectrum trade, a change of technology, service application and geographical usage is allowed, with different levels of restrictions:

- **Change of technology and service application** – The change of licence terms is only permitted by Ofcom on a case-by-case basis to ensure no inference is caused by the change. However, many of the recent spectrum releases are technology- and application-neutral, such as the 1800MHz spectrum released in 2006, the 800MHz and 2600MHz spectrum released in 2013, the 900MHz spectrum released in 2014 and the 2.3GHz and 3.4GHz spectrum to be released in 2017–2018. However, Ofcom will apply "*technical licence conditions … consistent with national and international spectrum assignments*" [105] to minimise interference and harmonisation concerns with any changes in service.

- **Change of geographical usage** – The break-up of a spectrum lot into different geographies or frequencies is allowed for partial transfers.

Interference management

Ofcom provides guidelines on interference for each licence, and takes it into consideration when evaluating a change-of-use application. It also manages interference disputes between parties.

Process for completing spectrum trades

The spectrum trading process is a combination of an ex-ante and ex-post approach, as follows:

- The licence holder submits the trading application form to the regulator.

- The basic details of the proposed trade are published on the Trade Notification Register (TNR). Interested parties are invited to submit details of any competition concerns on the deal within ten working days.

- Ofcom checks the authorisation of the trade, and may request additional data from related parties. Ofcom aims to notify the decision as to whether there is a possible distortion of competition that needs further competitive assessment within 20 working days.

- In the case of further competitive assessment, Ofcom will invite analysis and evidence from the trade deal participants and third parties. The assessment will consider the following criteria:

    — the possible impact of the deal on the competition landscape, such as prices, quality of service and innovation prospects

105 Source: Ofcom (2013), *2.3 and 3.4GHz spectrum award: Consultation on a 3.4GHz band plan, varying UK Broadband Limited's licence and a call for inputs on other aspects of the award*. Available at https://www.ofcom.org.uk/consultations-and-statements/category-2/2.3-3.4-ghz.

— efficiencies and potential benefits from the trade.

- Ofcom announces its decision on whether the trade is permitted.
- The trade is executed and the trade status is updated in the TNR.

In the case that competition issues arise after the spectrum trade has already commenced, Ofcom will address them on an ex-post basis in accordance with the Competition Act 1998, supplemented by the Communications Act 2003 and the Enterprise Act 2002.[106]

The process of leasing spectrum is simpler process as it comprises only the negotiation between the spectrum holder and the lessee, with no requirement to notify Ofcom. However, the agreement must comply with the licence's conditions.

Regulatory measures related to spectrum trading

Although the spectrum trading process already includes an assessment of competition distortion, Ofcom indicated that it may impose conditions on licences such as spectrum caps, on a case-by-case basis to prevent anti-competition issues.

Furthermore, some licence classes such as fixed–services have restrictions on geography and frequency breakdown for partial trades. Some other licence types only allow total exclusive trades, not any other type of trade.

Provision of information on spectrum and spectrum trading

The information related to spectrum and spectrum trading in the UK is provided through different sources:

- The UK Plan for Frequency Authorisation (UKPFA) presents data on the available frequencies for assignment, frequencies' assignment purpose, and whether the spectrum licences are tradable.[107]
- The Wireless Telegraphy Act Register (WTR) provides information on individual tradable licences, including licence owner details and the spectrum detail.[108]
- The Transfer Notification Register (TNR) provides basic details about all proposed and approved spectrum transfers, including the deal status.[109]

---

106 Source: Ofcom (2014), *Ensuring effective competition following the introduction of spectrum trading*. Available at https://www.ofcom.org.uk/consultations-and-statements/category-3/sec.

107 https://www.ofcom.org.uk/spectrum/information/spectrum-info-faq/ukpfa.

108 https://www.ofcom.org.uk/research-and-data/data/opendata.

109 https://www.ofcom.org.uk/spectrum/information/spectrum-info-faq/tnr.

A.3.3 Volume of spectrum trading activity

The volume of spectrum trading activity in mobile bands is low in the UK. Below are two notable spectrum trades that have occurred in the UK:

- **Trade prompted by mergers and acquisitions** – As part of the regulatory condition for the merger between Orange and T-Mobile to create EE, the new entity was required to divest 2×15MHz of its 1800MHz to preserve competitive dynamics in the market, and EE chose to trade the spectrum to Three in 2012. The trade resulted in Three rolling out 4G services in the 1800MHz spectrum, creating new service offerings in the market. Following the transaction, Three became liable for the annual licence fees associated with the licence.

- **Trade prompted by the introduction of new technologies** – Spectrum in the L-band was initially acquired by chipset manufacturer Qualcomm to provide a test bed for the then latest advanced wireless services. However, after the European Union (EU) harmonised the 1452–1492MHz band for mobile network supplemental downlink (SDL) in May 2015, the spectrum became more valuable to be used for mobile communications purposes. After getting regulatory clearance to change the technical conditions of its L-band spectrum to suit public mobile purpose, Qualcomm traded its L-band spectrum licences to mobile network operators Three and Vodafone to allow them to supplement their spectrum holdings and expand their mobile networks. While Qualcomm originally acquired the spectrum for GBP8.3 million in 2008,[110] its sale to Vodafone and Three reportedly yielded approximately GBP200 million.[111]

A.4 USA

The Federal Communications Commission (FCC) oversees the regulation of the communications sector in the USA, including wireless, wireline, satellite and broadcasting services. Furthermore, the FCC oversees spectrum-licensing management for non-federal usage.

A.4.1 Background on spectrum trading

Primary awards of spectrum

The FCC allocates spectrum via two types of mechanism with limited licence duration:

- **Market-based mechanism** – Spectrum rights for most commercial licences – such as public mobile, fixed–wireless, fixed, television and radio services – are allocated through auctions. The spectrum is auctioned per single regional lot and licences have an indefinite duration.

---

110 Source: Qualcomm (2008), *Qualcomm Wins 40MHz of L-Band Spectrum in UK Auction*. Available at https://www.qualcomm.com/news/releases/2008/05/16/qualcomm-wins-40-mhz-l-band-spectrum-uk-auction

111 Source: TeleGeography (2015), *Qualcomm sells L-Band spectrum to Vodafone UK and Three UK*. Available at https://www.telegeography.com/products/commsupdate/articles/2015/08/26/qualcomm-sells-l-band-spectrum-to-vodafone-uk-and-three-uk/

- **Administratively assigned** – Other spectrum, including the spectrum for private usage, is administratively assigned.

Introduction of spectrum trading

The FCC has introduced measures to promote the secondary spectrum market since 1996. However, all transactions were subject to approval by the FCC.

In May 2003, the FCC passed a Report and Order and a Further Notice of proposed rulemaking in the matter of promoting efficient use of spectrum through elimination of barriers to the development of secondary markets,[112] which grant most wireless radio licensees the rights to enter spectrum trades. The requirements contained therein were designed to ensure a faster process, increase spectrum access, promote spectrum efficiency and facilitate market competition among service providers.

As the spectrum in the USA is auctioned per single regional lot, operators might own different bands for different regions, resulting in inefficiency allocation of spectrum. Therefore, spectrum trading has been allowed to assist operators in harmonising their spectrum portfolio.

A.4.2 Implementation of spectrum trading

Scope of spectrum eligible for trading[113]

The tradable spectrum includes commercial bands such as those used for the provision of public mobile, fixed–wireless, fixed, television and radio services.

Forms of spectrum trading

The types of transactions allowed in the USA are transfers, leases and subleases:

- **Transfer**:
  - *Total transfer* – the transfer of a complete spectrum lot.
  - *Partial transfer* – the transfer of a segregation of a spectrum lot.

112 https://www.federalregister.gov/documents/2000/12/26/00-32789/promoting-efficient-use-of-spectrum-through-elimination-of-barriers-to-the-development-of-secondary

113 The full list of tradable spectrum can be found in the FCC's Report and Order and Further Notice of Proposed Rulemaking in the matter of Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets (2003), Appendix B, 1.948.

- **Leasing**:

  — *Spectrum Manager Lease* – the spectrum holder retains both legal and working control of the spectrum, which means that the spectrum holder is accountable for any lessee's violations. This transaction does not require prior consent of the FCC, but requires notification to the FCC.

  — *De Facto Transfer Lease* – the spectrum holder retains the legal control, but transfers working control to the lessee. Therefore, the lessee is responsible for ensuring its operational compliance with the FCC's regulations.

- **Subleasing** – The lessee can sublease the spectrum, unless prohibited by the spectrum holder. Acting as a spectrum manager, the leaseholder must notify the FCC about the sublease.

Spectrum liberalisation (extent of technology and service-neutral spectrum)

Licences are permitted to modify spectrum use in the following ways:

- **Change of technology** – The FCC has adopted a technology-neutral approach for its spectrum licences. However, service-neutrality has not been mentioned by the FCC; therefore, it should not be permitted in spectrum trading.

- **Change of geographical usage** – The partitioning of a spectrum lot into different geographies or frequencies is allowed for secondary trading.[114]

Interference management

Licence holders and spectrum users are required by the FCC to minimise the potential for harmful interference to adjacent bands. The FCC's interference rules for cellular licensees similarly require that licensees protect adjacent cellular licensees from interference.[115]

Process for completing spectrum trades

In the USA, spectrum trading is typically allowed immediately following the primary spectrum awards. Spectrum transfers and leases are categorised into two groups:

- **Spectrum trades that are eligible for 'immediate approval process'** – These are the trades for certain spectrum that do not "*raise potential concerns relating to eligibility and use restrictions, foreign ownership restrictions, designated entity/entrepreneur restrictions, or*

---

114 Source: FCC (2004), *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*. Available at https://www.fcc.gov/document/promoting-efficient-use-spectrum-through-elimination-barriers-1.

115 Source: FCC (2000), *Principles for Promoting the Efficient Use of Spectrum by Encouraging the Development of Secondary Markets*. Available at https://www.fcc.gov/document/promoting-efficient-use-spectrum-through-elimination-barriers-development-secondary-3.

competition".[116] In terms of competition, the spectrum being traded must not overlap with the proposed spectrum acquirer or lessee's wireless service spectrum.[117] These spectrum trades only require notification to the FCC, and are approved immediately. The trade then gets published on the FCC's public online registry, the Universal License System (ULS).

- **Spectrum trades that require 'streamlined approval'** – These are the trades that do not qualify for immediate approval. They get approved within 21 days of public review.

For immediate-approval process, third parties can petition to deny the trade within 30 days of approval. The spectrum trades that require streamlined approval can get petitions to deny within 21 days of public review prior to approval.

If concerns are raised under either process, the FCC will 'offline' the application and then re-examine the deal within 90 days using ex-ante measures. The assessment criteria include eligibility and use restrictions, foreign ownership restrictions, designated entity/entrepreneur restrictions, and competition. The FCC will also deal with arising competitive outcomes from the trade on an ex-post basis.

Subleasing deals only require notification to the FCC, and a written consent from the licensee.

Regulatory measures related to spectrum trading

The spectrum trade approval process used in the USA already includes an assessment of competition distortion.

Provision of information on spectrum and spectrum trading

The ULS records data on licences available for transfer or lease, each trade details, licence conditions, licence holder data and the administrative procedure relating to the licence.

A.4.3 Volume of spectrum trading activity

Figure A.3 shows the trading volume of spectrum transfers and spectrum leases in the USA as recorded in the ULS. Spectrum leases account for roughly 90% of the spectrum trading deals in the market over the last three years, with most trades taking place in public mobile and fixed bands.

---

116 Source: FCC (2004), *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*. Available at https://www.fcc.gov/document/promoting-efficient-use-spectrum-through-elimination-barriers-1.

117 This applies when the proposed spectrum acquirer or lessee holds a direct or indirect interest of 10% or more in the existing spectrum.

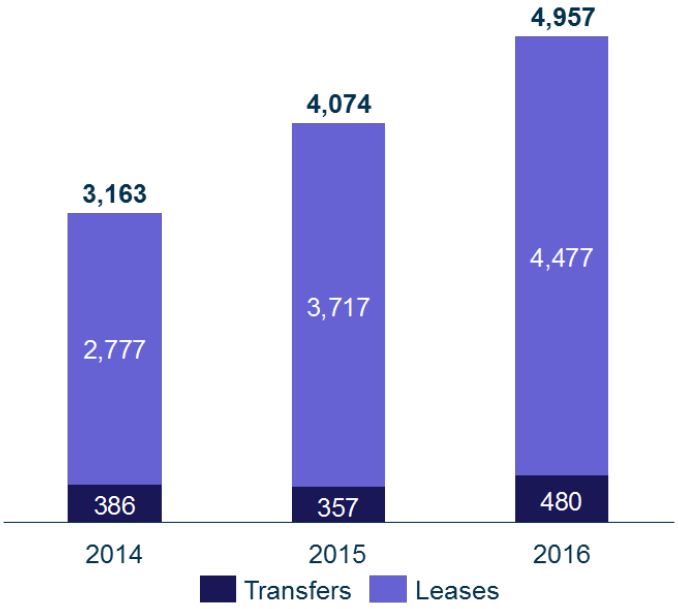


Figure A.3: Volume of spectrum trades in the USA, by type of trade [Source: ULS, 2017]

Below we provide a set of examples of notable spectrum trades in the USA:

- **Spectrum swap to improve spectrum harmonisation and geographical coverage** – In 2014, Verizon transferred 23 blocks of 700MHz spectrum to T-Mobile, in exchange for 19 blocks of spectrum in the advanced wireless services (AWS) band, 8 blocks of spectrum in the personal communications services (PCS) band. The deal also involved a monetary compensation of USD2.4 billion from T-Mobile to Verizon[118]. The trade allowed both operators to hold larger blocks of contiguous spectrum and a more desirable spectrum holding, potentially enabling each to deliver higher-capacity and improved data throughput speeds. The transaction enabled T-Mobile to use the previously un-utilised 700MHz spectrum to roll out 4G services at a lower cost.

  In 2011, Leap Wireless reached a spectrum swap deal with Verizon whereby Leap Wireless acquired 12MHz of 700MHz spectrum covering Chicago in exchange for over 36 blocks of AWS and PCS bands across 16 states[119]. Leap Wireless had previously announced that it "*lacks sufficient depth*" to launch LTE services in the Chicago area.[120] The deal enabled Leap Wireless to receive net cash proceeds of more than USD100 million, allowing it to support ongoing deployment of LTE network technology. The deal also helped to release Leap Wireless from the roll-out commitment of its unused licences. This allowed Leap Wireless to grow to become the fifth-largest operator in the USA, before eventually being acquired by AT&T in 2014.

118 Source: T-Mobile buys Verizon's 700 MHz A Block spectrum for $2.4B, FierceWireless, January 2014

119 Source: Leap, Verizon Wireless exchange spectrum, Reuters, December 2011

120 Source: @ CTIA: Leap set to launch LTE this year, signs roaming deal with LightSquared, RCRWirelessNews, March 2011.

- **Potential 5G spectrum acquisition** – In July 2016, the FCC introduced flexible-use service rules in frequency bands above 24GHz (namely, the 28, 37, 39 and 64–71GHz bands), making them suitable for 5G deployment. The FCC also established that its efforts in this area are ongoing by requesting comment on the possible authorisation of fixed and mobile spectrum use in the 24, 32, 42, 47, 50 and 70/80GHz bands, as well as in bands above 95GHz.[121] Thus, leading operators have been seeking to acquire millimetre wave (mm-wave) spectrum in recent years. Below is the list of related spectrum deals:

  — In November 2017, the FCC approved Verizon's purchase of spectrum in the 28 and 39GHz bands from Nextlink Wireless, a subsidiary of XO Communications. Verizon has been leasing these spectrum from Nextlink Wireless since 2016[122]

In February 2018, T-Mobile bought 1150MHz of spectrum in the 28-31GHz band from First Communications for an undisclosed fee[123] Secondary spectrum trading thus allows leading operators to gain access to crucial mobile spectrum assets that are potential 5G bands, which could differentiate their services as 5G becomes a mainstream technology in the future. In the USA, the FCC has indicated that 5G will be deployed in already-assigned spectrum. As the perpetual spectrum licensing system is adopted in the USA, therefore American operators rely more on the secondary market to obtain 5G spectrum. In contrast, in European and Asia markets, regulators plan to offer new 5G spectrum bands by auction, thus there is expected to be less activity in the secondary market for spectrum in those regions than in the USA.

A.5 Canada

The Department of Innovation, Science and Economic Development Canada (ISED), formerly known as Industry Canada, is responsible for spectrum management in Canada, through the Department of Industry Act, the Radiocommunication Act, the Radiocommunication Regulations, and with due regard to the Canadian telecoms policy objectives set out in Section 7 of the Telecommunications Act.

Rules for spectrum trading are defined by ISED in the Framework Relating to Transfers, Divisions and Subordinate Licensing of Spectrum Licences for Commercial Mobile Spectrum ('the Framework'). ISED also releases Client Procedures Circulars 2-1-23, Licensing Procedures for Spectrum Licences for Terrestrial Services (the 'Spectrum Licence Procedures'), which describe the various procedures or processes to be followed by the public when dealing with ISED. Spectrum Licence Procedures are amended when there are changes made to frameworks relating to spectrum management.

---

121 Source: FCC (July 2016), Report and Order and Further Notice of Proposed Rulemaking.

122 Source: In the Matter of Application of Cellco Partnership d/b/a Verizon Wireless and XO Holdings. For Consent to Transfer Control of Local Multipoint Distribution Service and 39 GHS Licenses, memorandum opinion and order, FCC, November 2017

123 Source: T-Mobile to buy 1150 MHz of millimeter-wave spectrum covering Ohio for 5G, FierceWireless, February 2018

A.5.1 Background on spectrum trading

Primary awards of spectrum

Where the demand for spectrum is not expected to exceed the available supply, ISED generally uses a first-come, first-served licensing process to award spectrum licences.[124] In instances where the demand for spectrum is expected to exceed supply, a competitive licensing process, such as an auction, is generally used. The Radiocommunication Act was amended in June 1996 to give the Minister of Industry explicit authority to use spectrum auctions, especially in areas where the use of market forces to assign licensees was in the public interest.

ISED will generally consider the following broad conditions in determining whether an auction process will be used as the spectrum-assignment mechanism:

- whether the demand for spectrum is expected to exceed the available supply, and
- whether government policy objectives can be fully met using an auction.

As such, ISED has deemed that the use of auctions as a spectrum-assignment mechanism may not be appropriate for broadcasting licences, priority services (i.e. radiocommunications systems vital to national sovereignty and defence, law enforcement, public safety and emergency services), and satellite services.

Spectrum licences issued in auctions typically have commercial mobile applications and are issued on a regional basis. They also have transferability and divisibility rights, allowing the spectrum to be traded in the secondary market. Licences issued have terms of up to 20 years, based on the specific spectrum auctioned. Licences have a high expectation for renewal, unless there is a breach of licence conditions, a requirement for spectrum re-assignment or an overriding policy need.

Introduction of spectrum trading

Secondary market for spectrum was introduced in Canada after the auction of the 24GHz and 38GHz bands in 1999. ISED noted that services and technologies associated with 24GHz and 38GHz spectrum were new and developing, and bidders would face some uncertainty in determining the exact amount of spectrum they may require in various service areas. It was believed that more information about market opportunities and technology would become available post-auction, thus permitting secondary-market transactions, which would enable spectrum to be more efficiently allocated.

Similarly, to encourage competition, more efficient spectrum usage (through increasing contiguity of spectrum) and earlier service to unserved or underserved areas, ISED also permitted licences to be transferred in whole, or divisible in both the bandwidth and geographical dimensions.

---

124 Source: Industry Canada (2011), *Framework for Spectrum Auctions in Canada*. Available at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01626.html.

Although a three-year moratorium was initially considered to be legislated to restrict transfer and division of licences that were to be auctioned, ISED sufficed that there are sufficient safeguards in place (eligibility requirements, requirement for upfront payments and penalty fees) to discourage speculative bidding for licences.

ISED was conferred the right to permit spectrum transfer under sub-paragraph 5(1)(a)(i.1) of the Radiocommunication Act, where ISED may issue spectrum licences in respect of the utilisation of specified radio frequencies within a defined geographical area.

The Spectrum Licence Procedures were enhanced in 2005[125] to include spectrum issued under a comparative review or 'first-come, first-served' process. Previously, this spectrum generally did not have the enhanced transferability and divisibility rights of spectrum licences issued under auctions, and thus could not be transferred. The enhancement allowed licensees to request for transfer of the licence where the licence accompanies other business assets and is being used as part of a going concern.

In 2007, regulation was further enhanced to permit subordinate licences,[126] which allow for more efficient use of spectrum by permitting licensees to share spectrum[127] with third parties. A subordinate licence is defined as a licence issued by the Minister under paragraph 5(1)(a) of the Radiocommunication Act that is related to a primary licence, and is conditional on the primary licence meeting all regulatory requirements, including the terms and conditions of the licence.

The 2013 revision of the commercial mobile spectrum licensing framework thus sought to add an additional level of scrutiny to such agreements, to prevent windfall gains by either party. It regulates that prospective and deemed transfers would also need to be reviewed by ISED before review by the Competition Bureau. It also details the specific criteria considered and the process used when spectrum licence transfer applications are reviewed.

A.5.2 Implementation of spectrum trading

Scope of spectrum eligible for trading

Most auctioned licences, largely for commercial mobile spectrum, have enhanced transferability rights accorded to it. The following table shows the spectrum that can be traded in Canada.

125 Source: Industry Canada (2005), *CPC-2-1-23, Licensing Procedure for Spectrum Licences for Terrestrial Services*.

126 Source: Industry Canada (2007), *CPC-2-1-23, Licensing Procedure for Spectrum Licences for Terrestrial Services Issue 2*. Available at https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/cpc2123i2e.pdf/$FILE/cpc2123i2e.pdf

127 Defined by ISED as being able to enter into arrangements which allow another party to operate within a portion of their frequency or geographical area without having to completely transfer their spectrum licence(s).

Figure A.4: Tradeable spectrum in Canada [Source: ISED, 2017]

Primary allocation (secondary allocation)	Band	Spectrum frequency	Remarks
Mobile, fixed	Advanced wireless services (AWS)	1710–1780MHz 2110–2180MHz	Regional basis
Mobile (fixed)	Air ground services[128]	849–851MHz 894–896MHz	National basis
Mobile, fixed, broadcasting (space research, radio astronomy, Earth exploration-satellite)	Broadband radio services (BRS)	2500–2690MHz	Regional basis
Fixed, mobile (Earth exploration-satellite)	Broadband wireless access (BWA)	24.25–24.45GHz (lower) 25.05–25.25GHz (upper) 38.70–39.80GHz	Regional basis
Mobile (fixed)	Cellular	824–849MHz 869–894MHz	Regional basis
Broadcasting, fixed, mobile	Mobile broadband services (MBS)	698–756MHz	Regional basis
Mobile, fixed	Personal communications services (PCS)	1850–1995MHz	Regional basis
Mobile, fixed, land mobile (amateur)	Wireless communications services (WVA)	2305–2320MHz (lower) 2345–2360MHz (upper)	Regional basis
Mobile, fixed, fixed-satellite, radiolocation (amateur)	FWA	3475–3650MHz	Regional basis

Spectrum licences without transferability and divisibility rights can only be transferred as part of a going concern and cannot be sold, divided or leased. This would apply to spectrum attained through comparative review or on a first-come, first-served basis.

Forms of spectrum trading

The Radiocommunication Act permits all spectrum licences with transferability and divisibility rights to perform the following transactions:

- **Licence transfers** – Ownership of the licences is transferred to a third party. Licences can be transferred in full or they can be divided by bandwidth or by geography (the minimum unit is one spectrum grid cell[129] or a portion of a census dissemination area). In the case where licences

[128] For the provision of air-to-ground data and communications services to private and commercial airlines in Canadian airspace.

[129] A spectrum grid cell is a hexagonal figure with an area of 25 square kilometres. All spectrum grid cells are defined in the ISED (Spectrum Management) Client Procedures Circular 2-1-16.

are divided, new spectrum licences will be issued by ISED once the licence transfer request is approved. Licensees are permitted to enter agreements that provide for future licence transfers (e.g. option agreements, security agreements), subject to ISED's review.

- **Subordinate licencing** – Licensees can enter into agreements to allow a third party to use their licenced spectrum or a portion of their frequency or geographical area, without having to completely transfer their spectrum licences (i.e. spectrum sharing). Responsibility of compliance to terms and conditions would continue to rest with the primary licensees. Leasing agreements are also permitted under subordinate licencing. The leasing term is based on the agreement between the lessor and lessee and can be up to the entire tenure of the original spectrum licence. All subordinate licences do not have transferability or divisibility rights.

On a case-by-case basis, ISED would also consider spectrum exchange requests from licensees. In 2015, ISED approved Bell Mobility's request to exchange seven licences in its 2500MHz spectrum with licences that remained unassigned at the 2015–2500MHz auction. The exchange allowed Bell Mobility to increase the contiguity of its spectrum and achieve greater spectrum efficiency.

Spectrum liberalisation (extent of technology and service-neutral spectrum)

ISED issues licences that are technology-neutral (i.e. licensees generally have the maximum-possible flexibility in determining the technologies that they will employ).

In Canada, service-neutrality is largely band-specific. Industry Canada (the predecessor to ISED) deemed spectrum in the 24GHz and 38GHz bands to have a variety of different business plans and technologies that can be employed, therefore it was auctioned as service-neutral in 1999.[130] Beyond the need to conform to the applicable Canadian spectrum allocation, only those limitations required for interference-management purposes will generally be imposed.

Interference management

All spectrum licence holders are responsible for ensuring that their radio system do not cause harmful interference. For new installations and modifications which have the potential to cause interference, spectrum licensees are required to co-ordinate with adjacent channel operators before operating a new or modified radio system.

Primary spectrum licence holders are also subject to international co-ordination agreements between Canada, the USA and other foreign administrations.

130 Source: Industry Canada (1999), *Policy and Licensing Procedures for the Auction of the 24 and 38GHz Frequency Bands*. Available at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01820.html.

Process for completing spectrum trades

All licence transfers, division of licences and subordinate licencing requests must undergo an ex-ante review by ISED.

The 2013 amendment to the Framework details the specific criteria considered and the process used when commercial mobile spectrum[131] transfer applications are reviewed to increase the transparency of the review process. This was after ISED blocked the sale of a new entrant, Mobilicity, to Telus, stating it would not approve deals that led to an "*undue concentration*" of spectrum in the hands of one player. The review criteria are as follow:

> *a) the current licence holdings of the Applicants and their Affiliates in the licensed area;*
> *b) the overall distribution of licence holdings in the licensed spectrum band and commercial mobile spectrum bands in the licensed area;*
> *c) the current and/or prospective services to be provided and the technologies available using the licensed spectrum band;*
> *d) the availability of alternative spectrum that has similar properties to the licensed spectrum band;*
> *e) the relative utility (e.g. above and below 1GHz) and substitutability of the licensed spectrum and other commercial mobile spectrum bands in the licensed area;*
> *f) the degree to which the Applicants and their Affiliates have deployed networks and the capacity of those networks;*
> *g) the characteristics of the region, including urban/rural status, population levels and density, or other factors that impact spectrum capacity or congestion; and (h) any other factors relevant to the policy objectives outlined in this Framework that may arise from the Licence Transfer.*

Additional amendments to the Framework in 2013 seek to regulate other types of agreements that would impact the competitive market for commercial mobile services and impede policy objectives of the Framework. On top of licence transfers and subordinate licensing, ISED would also require the following transactions to be submitted for review:

- **Deemed transfers** – Agreements which lead to a change of control of the licences to a person other than the licensee, however the name of the licensee may or may not change. This can be a result of a change of ownership, strategic alliances, joint ventures or any full or partial right or interest in a spectrum licence and negative control[132] situations. Deemed transfers will be treated as licence transfers during ISED's review of the trade agreement.

- **Prospective transfers** – Agreements that provide for a future transfer of either a spectrum licence or a subordinate licence, including option agreements, rights of first refusal or first offer

131 Spectrum in cellular, PCS, AWS, BRS, WCS and MBS – the 700MHz band.

132 An agreement that prevents a licensee from entering into an agreement with a competitor to transfer a licence.

and security agreements. The licence holder would be required to seek a review within 15 days of entering such agreements. The agreement will be evaluated as though the future licence transfer arising from the relevant agreement has been made. The review would be treated confidentially, and ISED will provide a decision on whether the agreement meets the policy objectives of the Framework. In cases where ISED has issued a decision stating that the prospective transfer does not meet the policy objectives, the licensee will have 90 days from the date of the decision to revise or annul the original agreement.

ISED will normally complete any review of transfer requests, deemed transfers and prospective transfers within 12 weeks from the time of receipt of all required information.

Regulatory measures related to spectrum trading

Spectrum licences are under the remit of the Competition Act. Thus, the Competition Bureau will conduct its review together with an ex-ante regulatory review by ISED.

ISED also imposed pro-competitive measures such as restricting the participation of certain entities in an auction. ISED would restrict a telecoms service operator from participating in an auction if: 1) it possesses significant market power in a region covered by the licence to be auctioned; 2) a new entrant is likely to use the licence to provide competition services in the region; and 3) the anti-competitive effects of the operator gaining the licences are more than the potential economies of scope arising from the integration of the spectrum to be auctioned and the operator's existing spectrum holdings.

In addition, some spectrum auctions have moratorium for spectrum trading within a stipulated period from the date of individual licensing. For example, a moratorium was placed for licences awarded in the 2008 AWS auction that introduced new entrants and smaller competitors in the Canadian mobile market to compete with the three major mobile incumbents: Telus, Bell and Rogers.

Recent auctions have featured spectrum caps to ensure competitive markets, i.e. one that allows four or more operators to hold licences in every region. An example is the 2500MHz wireless spectrum auction which included spectrum caps and smaller geographical licence areas.

Provision of information on spectrum and spectrum trading

ISED maintains a publicly accessible database listing all licences and respective licensees. It also maintains a register of spectrum trades and publishes a summary of its decisions with respect to licence transfers and prospective transfers.

A.5.3 Volume of spectrum trading activity

Canada has an active secondary market for spectrum. Hundreds of spectrum licences are traded annually, as shown in Figure A.5, most of which are public mobile spectrum licences. However, this volume might be overstated as each trade might involve multiple licences in different geographies.

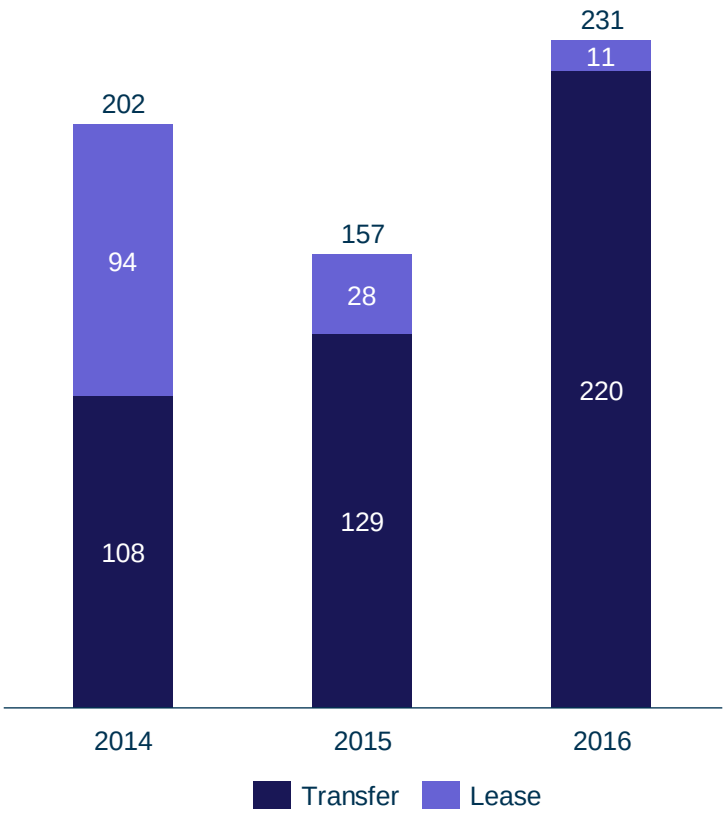


Figure A.5: Volume of spectrum trades in Canada, 2014–2016 [Source: ISED, 2017]

Some spectrum trading activities have been triggered following the expiry of moratorium for AWS-1 spectrum auctioned to new entrants in 2008. Some of these new entrants had since struggled to gain a foothold in the market and faced financial difficulties in growing their network, thus resulting in the underutilisation of their awarded spectrum. The following trades have helped to correct market inefficiencies:

- In August 2015, Wind Mobile traded its unused 1700/2100MHz spectrum licences to the two regional telecoms operators Manitoba Telecom Services (MTS Allstream) and SaskTel, which plans to use the spectrum to expand its existing 4G LTE bandwidth[133].

- Rogers received regulatory approval to buy Videotron's 1700/2100MHz (AWS-1) mobile spectrum licence in the Greater Toronto region for approximately CAD184 million, in June 2017[134]. Rogers initially agreed to purchase the spectrum from Videotron in May 2013, after expiry of the moratorium, however the deal was put on hold due to a review of the federal spectrum licence transfer policies.

In Bell's acquisition of Manohita Telecom Services (MTS) in 2016, spectrum trading was used to divest MTS's wireless spectrum, subscribers and retail locations to Telus and Xplornet to alleviate

133 Source: Wind selling LTE spectrum in Prairies to MTS, Sasktel; MTS moves to divest Allstream, TeleGeography, August 2015

134 Source: Rogers buys Videotron's AWS-1 spectrum in Greater Toronto for CAD184m, TeleGeography, June 2017

anti-competition concerns, as requested by the national regulator and competition authority[135]. The acquisition levelled the playing field among the three main operators – Bell, Telus and Rogers – and maintained a fourth player with the introduction of Xplornet. Details of the deal are as follow:

- Bell received 10 spectrum licences consisting of 2×10MHz of 2GHz (AWS-1) spectrum, 2×5MHz of 2GHz (AWS-1) spectrum, 2×15MHz of 1900MHz (PCS), 5MHz of 1600MHz, and 2×10MHz of 800MHz in Manitoba, Winnipeg Brandon and Deception bay regions as part of the deal. Post-merger, Bell will move from fourth to the largest mobile operator in Manohita.

- Xplornet will receive 24 700 subscribers and six retail stores along with 2×5MHz of 2GHz (AWS-1) spectrum, 2×10MHz of 2.5GHz (BRS) spectrum in Winnipeg and Brandon region, along with 2×5MHz of 700MHz spectrum in Manitoba region. Financial terms for the Xplornet agreement were not disclosed. This would allow Xplornet, a rural Internet service provider (ISP), to launch wireless services in the region as the fourth mobile operator and supplement its existing base of more than 300 000 Internet and home phone customers in rural areas across Canada.

- Telus will pay Bell CAD300 million for 110 000 of MTS's contract wireless subscribers and 13 stores. This does not involve spectrum transfer but will increase Telus' market share in the Manohita region to 18% in 2016 from 10% prior to the deal.

Spectrum trading has also been used to harmonise spectrum holdings in Canada. In May 2016, Telus completed a spectrum-licence assignment and rationalisation agreement with Xplornet to transfer 3500MHz FWA spectrum licences, as well as undisclosed monetary consideration, in exchange for Xplornet's 2300MHz spectrum licences in similar regions[136]. After the trade, Telus would have 2300MHz spectrum in nearly every market in Canada, allowing Telus to build on its ecosystem of network infrastructure and devices to provide more robust mobile and fixed wireless broadband access to its users. Xplornet would complement its existing 3500MHz holdings with the swap, allowing it to enhance its LTE-TDD network and boost connection speeds of its fixed wireless service[137].

135 Source: To acquire MTS, Bell must sell assets and provide services to Xplornet, Competition Bureau of the Government of Canada, February 2017

136 Source: Transfer of Spectrum Licences Held by Xplornet Communications Inc. to TELUS Communications Company, ISED, April 2016

137 Source: TELUS Corporation – Management's discussion and analysis – 2016, Telus, February 2017

Annex B Case studies of markets in Category 2

In this annex, we review and assess three countries where spectrum trading is possible, but do not have a clear spectrum trading regime: Luxembourg, Singapore and Switzerland. We explore the methods that some of these countries employ, on top of spectrum trading, to maintain spectrum usage efficiency and manage spectrum transfers. We also highlight current practices used by the national regulators of these three countries throughout and after the spectrum-assignment process, considering each country's regulatory context.

B.1 Luxembourg

The Institut Luxembourgeois de Regulation (ILR) is a multi-sector regulatory authority, created with the objective of opening former state monopolies to competition. One of the areas it regulates is the radiofrequencies, through the law of 27 February 2011 on the management of radiofrequencies. ILR's responsibilities include:

- monitoring of technology developments
- establishment of frequency allocation plan
- designation and definition of the conditions of spectrum use, for transmission and reception
- publication of register of frequencies
- processing of applications for licences and assignments
- monitoring and controlling obligations under the law, licences and international radio spectrum agreements, including monitoring spectrum use, and identify potential interference occurrences.

ILR also regulates other electronic communication network and services. There is a separate entity, the Competition Council, that regulates competition law issues in the telecoms sector under the law of 23 October 2011 on competition.

As a member of the EU, the ILR is mandated to implement decisions by the European Commission (EC), such as the Radio Spectrum Policy Programme (RSPP). However, the ILR has discretion to the extent spectrum trading is to be implemented in Luxembourg.

B.1.1 Background on spectrum trading

Primary awards of spectrum

Luxembourg is a small city-state of about 500 000 residents. Radiofrequency spectrum is thus allocated nationwide, and not regionally. Public consultations are usually conducted prior to the primary assignment to gauge the demand for the commercial mobile spectrum. Based on this, the ILR will decide if the award should proceed and, if so, which mechanism should be used in the spectrum assignment. Luxembourg has used both market-based (in the form of an auction) and administrative mechanisms in the primary award of spectrum.

There have been instances where the ILR decided against holding a primary assignment after the public consultation. As an example, in 2014, low levels of interest for the one remaining unused lot of 2×15MHz of spectrum in the 2.1GHz band, and the upcoming expiry of existing licences in the same band in 2017 and 2018, led to the conclusion by the government not to pursue an award.[138]

The ILR appears to have used a market-based mechanism through spectrum auctions to allocate spectrum. In the 2006, the 1900–1980MHz and 2110–2170 bands for UMTS services were put up for auction to new operators, while spectrum in the 900MHz band was available for bidding by both existing and new operators to operate GSM. The licences both had a duration of 15 years, with a coverage obligation of 95% nationwide.[139] Orange, then a 3G-only operator, received the GSM licence, while new entrant Astralis beat out LOL, a mobile virtual network operator (MVNO), for the UMTS licence for undisclosed amounts. However, it appears that the spectrum was not used to introduce a new entrant due to legal complications from the auction.[140]

In recent years, the ILR had opted to administratively assign and renew commercial mobile spectrum of the three existing MNOs – Post-Luxembourg, Orange and Tango – due to the lack of competition in the market. Recently assigned spectrum includes:

- **900MHz and 1800MHz (May/June 2012)** – The spectrum holdings of existing MNOs were renewed for another 15 years following a public consultation during which no other potential candidate expressed interest in the spectrum. Spectrum issued is service- and technology-neutral, with use-it-or-lose-it obligations within three years of the licence being issued, a coverage obligation of 95% of the population nationwide, and with minimum QoS standards specified.

- **800MHz and 2600MHz (24 December 2012)** – Spectrum assigned to existing MNOs following a public consultation during which no other potential candidate expressed interest in the spectrum. Spectrum conditions include use-it-or-lost-it obligations by 24 December 2014 (800MHz) and 29 February 2016 (2600MHz).

- **2100MHz (08 May 2017)** – Spectrum conditions include use-it-or-lost-it obligations by 01 January 2020.

---

138 European Commission (2015), *Implementation of the EU regulatory framework for electronic communication – 2015*, Commission staff working document.

139 Telecompaper (2006), *Luxembourg to auction more mobile spectrum*. Available at https://www.telecompaper.com/news/luxembourg-to-auction-more-mobile-spectrum--508394.

140 The result was contested in court, and the communications ministry annulled Astralis' concession in January 2008 after the Administrative Court ruled in favour of LOL. However, LOL had never attained MNO licence from the regulator to build their own 3G network. It appears to have operated through incumbent Post-Luxembourg's network, who it had a roaming agreement with to provision 3G services.

Extent of spectrum reassignment permitted

Luxembourg is part of the EU and consequently is regulated by EC directives. This includes adopting decisions under the RSPP, which was established in 2010 in a bid to harmonise spectrum trading across the EU. The objective of the RSPP was to set out "*policy orientations and objectives for the strategic planning and harmonisation of the use of spectrum, taking utmost account of the opinion of the RSPG [Radio Spectrum Policy Group]*".[141] It proposed making spectrum bands where flexible use has been introduced to be tradable, with common measures in place by Member States to prevent the accumulation of spectrum leading to dominant positions or the failure to use acquired spectrum.

The following harmonised bands have been identified under the RSPP for Member States to allow the trading or leasing of spectrum rights:

- 790–862MHz (800MHz band)
- 880–915MHz and 925–960MHz (900MHz band)
- 1710–1785MHz and 1805–1880MHz (1800MHz band)
- 1900–1920MHz and 2010–2025MHz (unpaired 2GHz bands)
- 1920–1980MHz and 2110–2170MHz (2.1GHz band)
- 2500–2690MHz (2.6GHz band)
- 3400–3800MHz (3.4–3.8GHz band).

In accordance with the RSPP, the provision to transfer the rights of spectrum use, and its underlying obligations, is legislated in Luxembourg through the amendment to the Law of 30 May 2005 (the '2011 Law'). There is no mention on the types of trades allowed (e.g. leasing).

Article 7 of the 2011 Law also established the duty of the regulator (ILR) to assist the Luxembourgish Minister of State (Media and Communications)[142] to identify the frequencies that can be transferred at the request of the transferee, and the definition of the specific procedures involved. In addition, commercial mobile spectrum awarded after May/June 2012 has included the covenant to make possible the transfer of rights of use associated with the spectrum awarded. This covers spectrum in the 800, 900, 1800, 2100 and 2600MHz bands.

However, as at March 2018, a formal procedure on spectrum trading has yet to be established. In the public domain, there has also been no record of spectrum transfers requests to the ILR.

141 Source: Proposal for a decision of the European Parliament and of the Council establishing the first radio spectrum policy programme.

142 *Ministère d'Etat (Service des médias et des communications).*

B.1.2 Analysis of the current mechanism on spectrum reassignment

In Luxembourg, commercial mobile spectrum is largely administratively assigned as interest from parties outside the existing MNOs is low. As MNOs have similar and contiguous spectrum holdings, the need for spectrum reassignment after the primary auction has decreased.

Additionally, due to VDSL and fibre availability, no spectrum in the commercial mobile services bands has been used to provide fixed–wireless services in Luxembourg. Fixed–wireless services were trialled in the past, with the ILR awarding LuxWiMAX spectrum in the 3.5GHz band in August 2007. However, its licence was withdrawn in May 2009, citing LuxWiMAX's failure to utilise the spectrum. This lack of competing services for commercial mobile spectrum could have decreased the need for spectrum trading.

In terms of promoting spectrum efficiency, there are safeguards like use-it-or-lose-it regulations tied to spectrum licences that allow only 2–3 years of dormancy before the ILR will act to revoke the spectrum licence if it is not utilised, as it had done with LuxWiMAX's 3.5GHz spectrum and LOL's 2.1GHz UMTS spectrum. Therefore, even though licences have long 15-year terms, underutilisation of spectrum is prevented. Additionally, coverage obligations also help to safeguard against hoarding of administratively assigned spectrum.

B.2 Singapore

The Info-communications Media Development Authority of Singapore (IMDA) oversees the issuance of telecoms licences and the management of radiofrequency spectrum, developing the policies and regulations governing the assignment of radiofrequency spectrum. As part of the Agency's purview, it also manages the distribution of all spectrum rights and the spectrum-assignment process. Previously managed by the Info-communication Development Authority of Singapore (IDA), the IDA was restructured and re-consolidated with another government agency to form the IMDA.

B.2.1 Background on spectrum trading

Primary awards of spectrum

Prior to 2001, all spectrum was allocated on an administrative basis and charged using a cost-plus recovery approach. In view of rapid technological changes, and competing demands from operators, the IDA reviewed its spectrum-assignment policy framework and now allocates spectrum through two types of mechanism:

- **Market-based mechanism** – Spectrum rights for public mobile commercial communications are allocated via an auction with a licence duration of 10–15 years,[143] after which the spectrum

[143] For example, the 700MHz licence awarded in 2016 has a duration of 14 years, while licences for the 900MHz, 2.3GHz and 2.5GHz spectrum were awarded in the same year for 15 years. The 1800MHz and 2.5GHz licences awarded in July 2013 have terms of 13 and 15 years respectively.

will be returned to the regulator. The spectrum awarded comes with service-provisioning and coverage obligations to minimise spectrum speculation, particularly among new entrants.

Spectrum caps have been introduced in the auctions to prevent any single operator from hoarding excessive spectrum and limiting other operators from having sufficient spectrum to offer viable mobile services. Some examples of these include:

— In the 2013 auction, the IDA imposed a spectrum cap of 110MHz across the 1.8GHz and 2.5GHz spectrum bands that were being awarded, and a 60MHz sub-cap for the 1.8GHz spectrum band.

— In the 2016 auction, the IDA imposed a 75MHz spectrum cap across the 700MHz, 900MHz, 2.3GHz and 2.5GHz spectrum bands that were being awarded. There were also sub-caps of 40MHz for the 700MHz and 20MHz imposed for the 900MHz band.[144]

- **Administratively assigned** – All other spectrum bands are administratively assigned, including those such as private-trunked radiofrequencies that are in substantial demand, serve mission-crucial needs and where assignment of the spectrum via an auction is not feasible. An administrative incentive pricing (AIP) mechanism is implemented to price radiofrequencies more closely to their market value.[145]

Extent of spectrum reassignment permitted

The IMDA has not established a spectrum trading regime in Singapore or done any public consultations on the issue. However, under the Telecommunications Regulations Act 13, the spectrum rights holder may, under written approval by the authority, assign whole or part thereof of its spectrum rights to another operator. Any intentions for reassignment of these rights will also need to be accompanied with details regarding the reassignment, for evaluation of approval by the IMDA.[146] Hence, spectrum transfers are allowed, although trading involving sub-division, leasing and change of use is not.

Any reassignment transaction will need to comply with the Telecommunication Act's "*codes of practice and standards of performance on telecoms*", which include a competition aspect – to prevent abuse by market dominance and ensure fair market conduct.

There have been several successful secondary mobile cellular and wireless broadband spectrum transfers that have been authorised by the IMDA. Additionally, when Packet One obtained WBA spectrum but was unable to fully utilise it, another spectrum transfer transaction to StarHub took place.

---

144 If there were no new entrant that won any of the spectrum in the New Entrant Spectrum Auction, the overall spectrum cap would be 100MHz. The sub-caps would be 40MHz for 700MHz, 30MHz for 900MHz, and 45MHz for the sum of 2.3GHz and 2.5GHz spectrum bands.

145 IDA, 2016, *Proposed amendments to the telecommunications (radio-communication) regulations.* Available at: https://www.imda.gov.sg/~/media/imda/files/inner/pcdg/consultations/20141217_telcomregulations/rr%20review%20explanatory%20memo_for%20publication.pdf?la=en.

146 Telecommunication Act (Chapter 323, Section 74).

Figure B.1: Overview of spectrum transfers approved by the IMDA in Singapore [Source: IMDA, Analysys Mason 2017]

Year	Overview of transfer	Nature of transfer and reasons for approval
2009	interTouch and Qmax applied for a transfer of interTouch's 20MHz of WBA spectrum to Qmax	interTouch did not use the spectrum, and a transfer would allow Qmax, which had launched a commercial network, to use the spectrum more effectively
2009	Pacnet Internet Corporation and Packet One applied for a transfer of 30MHz of Pacnet's WBA spectrum and facilities-based operator licence rights to Packet One for a deal worth USD2.04 million[147]	Pacnet was a dormant business and a transfer of licence and rights would allow Packet One to use the spectrum to provide supplementary bandwidth to existing telecoms operators
2013	Packet One and StarHub applied for a transfer of Packet One's WBA spectrum rights to StarHub. This involved a fee	Likely due to under-utilisation of the spectrum

The IMDA also has ex-post measures, which are triggered when an operator has contravened its spectrum licence terms, or when an operator has broken the IMDA's code of practice or standard of performance, in accordance with the Telecommunication Act. The operator might be required to pay a financial penalty, which cannot exceed the higher of the following: 10% of the operator's annual turnover from the business that benefits from the licence, or SGD1 million.

Instead of demanding a financial penalty, or in the case that the operator fails to commit the financial penalty within the period requested, the IMDA can decide to do any or all of the following:

- cancel the spectrum licence partially or wholly
- suspend the licence partially or wholly for a period the IMDA thinks is appropriate
- reduce the licence duration.

B.2.2 Analysis of the current mechanism on spectrum reassignment

The IMDA's current spectrum management policies ensure an efficient use of spectrum, through a system that provides sufficient transparency, flexibility and oversight for both spectrum users and the regulator.

By regularly updating the Radio Spectrum Master Plan and conducting public consultations before spectrum auctions on assignment format and rules, it creates awareness regarding spectrum assignment and use, and considers spectrum users' needs in policy formulation.

147 TeleGeography, 2009, *GPB offloads P1s; unit renamed Mobiliti One*. Available at: https://www.telegeography.com/products/commsupdate/articles/2012/04/23/gpb-offloads-p1s-unit-renamed-mobiliti-one.

Requirements such as coverage obligations also guarantee spectrum is adequately deployed, while spectrum caps ensure each operator has sufficient spectrum to offer viable services. Failure in fulfilling licence obligations result in a penalty, with a possible cancellation of the spectrum licence.

Finally, spectrum users can request for transfers, the sale of spectrum or a change of spectrum use post-assignment (with approval from the IMDA on a case-by-case basis) where there are compelling reasons (e.g. unutilised spectrum due to failure of a new entrant in entering the market). This needs to follow competition assessment based on the Telecommunication Act. Nevertheless, there is no public data on the IMDA's criteria in assessing spectrum re-assignment requests.

B.3 Switzerland

The Federal Communications Commission (ComCom) regulates the telecoms market in Switzerland. It was established by the Law on Telecommunications (LTC) of 30 April 1997, and consists of seven members nominated by the Federal Council. Under the Ordinance of ComCom concerning the Telecommunications Act, ComCom has delegated some of its responsibilities to the Federal Office of Communications (OFCOM). This includes:

- Granting, inter alia, radio licences that do not involve any telecoms services (e.g. amateur radio licences)
- preparation and management of the tender process as well as supervision of spectrum usage and fulfilment of coverage obligations post-spectrum assignment for all other radio licences[148]
- drafting of the national frequency allocation plan which it submits to the Federal Council for approval.[149]

B.3.1 Background on spectrum trading

Primary awards of spectrum

Spectrum is broadly assigned via two kinds of mechanisms:

- **Market-based mechanism** – Spectrum used for commercial purposes including mobile and some radio and television broadcasting licences[150] are assigned via an auction or beauty contest. A large amount of both low-frequency and high-frequency spectrum is typically released in a single auction. The auction format is designed such that participants indicate their spectrum needs by putting in a

148 Ordinance of the Federal Communications Commission concerning the Telecommunications Act, Article 1.

149 Regulation on frequency management and radio concessions, Article 62.

150 Spectrum rights for radio and television broadcasting use where both i) at least 75% of the available transmission capacity is used for the distribution of program with/without access rights and ii) at least 50% for the distribution of programs with access rights is not fulfilled will be issued via a public tender.

binding application with the amount of spectrum they desire across frequencies available, with spectrum assigned at the minimum reserve price if they are the only interested bidders.

The spectrum is released on a technology-neutral basis for a pre-determined duration of 10–20 years to ensure "*an optimal and future-proof allocation of frequencies*", as spectrum users are then able to flexibly re-farm spectrum in line with technological changes.[151] Afterwards, the spectrum will be returned to the regulator.

Operational and coverage obligations are imposed on new spectrum awarded to ensure effective deployment. Spectrum caps by frequencies as well as across frequencies are also introduced to prevent operators from hoarding excessive spectrum of any kind and limiting other operators from accessing it. For example, in the 2011 auction, ComCom released ~620MHz of spectrum and operators were limited to acquire a total of 40MHz in the 900MHz spectrum band, 50MHz within the total of 800MHz and 900MHz bands, 75MHz in the 1800MHz band, 60MHz in 2100MHz band, and a maximum of 270MHz across all FDD spectrum released.[152]

- **Administratively assigned** – All other spectrum bands are administratively assigned, including those for amateur radio communication, some radio and television broadcasting licences.[153]

In accordance with Article 23 of the Telecommunications Act, the regulator must ensure that the issuance of the spectrum licence must not prevent effective market competition.

Extent of spectrum reassignment permitted

ComCom retains the rights to amend or revoke the spectrum rights to guarantee important public interests; in 2003, ComCom revoked Firstmark Communications Switzerland's national WLL licence as it "*found that assigned frequencies were not being used as prescribed in the licence*".

Under the Telecommunications Act Article 24d paragraph 1, spectrum licences "*may be transferred in part or as a whole to a third party only with the consent of the licensing authority.*" Therefore, spectrum licence owners can transfer their spectrum rights after obtaining ComCom's approval. The Swiss government is in the process of revising the Telecommunications Act, with a view to encourage spectrum trading.[154]

At the time of writing this report, no approvals for spectrum trading have been published.

---

151 Federal Communications Commission, 2011, *ComCom maintains overall award of mobile spectrum.* Available at: http://www.comcom.admin.ch/aktuell/00429/00457/00560/index.html?lang=en&msg-id=39412.

152 OFCOM, *Annex III Auction rules for the combined award of spectrum in the 800MHz, 900MHz, 1.8GHz, 2.1GHz and 2.6GHz bands* (2011).

153 Regulation on frequency management and radio concessions, Article 26.

154 Source: Federal Council adopts message on partial revision of the Telecommunications Act, Federal Council, September 2017.

B.3.2 Analysis of the current mechanism on spectrum reassignment

Although legislation in Switzerland does not allow spectrum trading, spectrum transfers are permitted, enabling licences to change hands as the market evolves. Like many regulators, information on frequency allocation and assignment is transparent and publicly available, where possible. Spectrum is also assigned on a technology-neutral basis, and as per the 2011 auction, assigned on a sufficiently large-scale basis with spectrum caps to ensure each operator has sufficient low-frequency and high-frequency spectrum to meet its operational needs. Re-assigning spectrum from one use to another (e.g. 2G to 4G) relies on the regulator re-auctioning licences upon the expiry of the previous licence terms. This can cause complexity (e.g. if the end dates of licences in a frequency band do not align among all licensees). A further impact is that the regulator is required to undertake complex auctions of multiple frequency bands (e.g. the Swiss 'big bang' 4G auction).

Licence owners are also required to meet coverage obligations, failing upon which OFCOM has the rights to and will revoke assigned rights, as past precedent has shown. All these practices have helped ensure spectrum is efficiently deployed.

Spectrum users can engage in spectrum trading by requesting a transfer of spectrum licences with approval from ComCom, if they can justify that the transfer will not distort competition dynamics and that the new licensee will be able to fulfil licence requirements. However, there are no clear guidelines on the regulator's criteria for assessing spectrum trading requests, except for the Telecommunication Act, which prohibits any action that may prevent effective market competition.

The current reassignment mechanism appears adequate for the market. Given the sufficiently rigorous primary-assignment process, the general availability of spectrum through auctions and the flexibility for post-assignment transfer, the benefits of spectrum trading in Switzerland are unlikely to be significant.

Annex C Case studies of markets in Category 3

In this annex, we review and assess how countries without a spectrum trading regime maintain spectrum-usage efficiency and manage spectrum transfers, including the extent of spectrum re-distribution permitted following a primary assignment process. Two countries are included in this category: Japan and Mainland China. We highlight current practices by the regulators in these countries throughout and after the spectrum-assignment process, considering each country's regulatory context. We also assess why a trading framework has not been considered; however, the information on the topic is rather scarce.

C.1 Japan

Under the radio law, the use of radio spectrum in Japan is governed by the Ministry of Internal Affairs and Communications (MIC). MIC oversees both spectrum allocation and assignment, and works with two separate councils, the Radio Regulatory Council and the Information and Communication Council to consult on important issues related to spectrum regulation. The Radio Regulation Council also helps to manage disputes and lawsuits between spectrum users and MIC. In addition, it also surveys actual radio spectrum usage in three-year intervals and evaluates efficiency of usage. Its findings are then published and used by MIC in modifying the frequency assignment plan, where necessary and applicable.[155]

C.1.1 Background on spectrum management

Primary awards of spectrum

Spectrum is awarded via a beauty contest mechanism. MIC has maintained a stance since the 1990s that spectrum assignment by a market mechanism such as an auction is not desirable as it could lead to excessively high bids.[156]

Instead, a registered telecoms business can apply for a radio station licence with MIC. The application shall include among other things, the base stations that would be built, spectrum desired, network deployment details and technology used, based on MIC's requirements. Having considered the applications submitted and the availability of requested frequencies, MIC may approve the submitted plans and assign the frequencies for a period of five years. The validity of the plan may be further renewed at MIC's discretion.[157] In the scenario where there are multiple applications

---

155 Asia-Pacific Economic Cooperation, 2010, *Spectrum Management Policy in Japan.* Available at: http://mddb.apec.org/documents/2010/TEL/TEL41-LSG-RR/10_tel41_lsg_rr_007.pdf.

156 Taplin, Ruth. And Wakui, Masako., *Japanese Telecommunications: Market and Policy in Transition,* Routledge (UK, 2012).

157 Radio Law, 2017, Japan, Article 6, 13.

requesting for access to the same frequency range, MIC has the final discretion. Examples of how the MCI has previously chosen to award spectrum under scenarios of multiple applications include:

- Awarded spectrum in the 2.5GHz band to UQ Communications, KDDI's joint venture over Softbank, allegedly as the former has provided "*better utilisation plans for frequency assets inside building and tunnels*".[158]

- Divided the entire block of 3.5GHz block equally between Softbank, NTT Docomo and KDDI with accompanying conditions on network investments, construction commencement data and coverage obligations.[159]

Extent of spectrum reassignment permitted

Japan has ex-post measures that allows MCI to revoke or change access to assigned spectrum in the scenario an operator fails to adhere to the plans it submitted, or it assesses that the changes are necessary to ensure efficient usage.

No spectrum trading is allowed in Japan. The Radio Law does not provide for a change in radio station licensee except in a merger or inheritance scenario. In these scenarios, the inheritor, assuming he controls the entire business and licence, will become the new licensee and be required to fulfil the requisite conditions under the licence. Similarly, when a corporate is divided into one or more corporation, one of the new successor corporations can take over the spectrum licence with the permission of MIC.[160] As such, operators are not able to trade their licences freely under current laws.

C.1.2 Analysis of the current mechanism on spectrum reassignment

Through measures and policies implemented over the spectrum assignment process, MIC has a high degree of oversight, ensuring effective use of spectrum from its perspective. By awarding spectrum rights based on detailed deployment plans and for a short period of five years only, MIC can ensure the spectrum is deployed to societal benefit. Furthermore, it can revoke spectrum when an operator fails to adhere to deployment plans, allowing it to exert pressure on operators to efficiently deploy spectrum. A key issue is that when a decision is taken to re-allocate spectrum, the MIC needs to undertake detailed planning to implement this. Decisions and timing on re-assignment and new uses are therefore dependent on MIC rather than on market forces. There is therefore a risk that re-assignment does not occur in line with market requirements, if the MIC adopts a different approach. There are various instances of where frequencies bands have been used in Japan for a proprietary

158 TeleGeography, 2013, *Japan awards additional spectrum in the 2.5GHz band to UQ Communications.* Available at: https://www.telegeography.com/products/commsupdate/articles/2013/08/13/japan-awards-additional-spectrum-in-the-2-5ghz-band-to-uq-communications/.

159 GTI, 2014, *Japan released 3.5G TDD licences -- 3.5G TD-LTE commercialization is accelerating.* Available at: http://www.gtigroup.org/news/ind/2014-12-25/5208.html.

160 Radio Law, 2017, Article 20.

use that does not align with international harmonisation and a detailed action plan has been required from MIC to re-assign these bands for harmonised uses.[161]

In practice, MIC does not appear to revoke or deny request of renewal of spectrum by spectrum users, particularly for mobile commercial spectrum given the high capital outlay required to build the networks. Nonetheless, the existence of such mechanisms gives flexibility to ensure existing licensees can renew spectrum rights if required. The key risk, as noted above, is that redistribution of spectrum and re-assignment from potentially lower value to higher value uses as markets evolve cannot occur without MIC's involvement. This causes potential inefficiencies (i.e. lacks market responsiveness) as well as requiring additional resource within the MIC to plan for spectrum re-distribution. However, frequencies are reviewed and (re)assigned in five-year terms, giving MIC considerable opportunity to respond to market changes. This thereby eliminates some of this potential inefficiency.

C.2 Mainland China

Telecoms operators in Mainland China are regulated under the Telecommunications Regulations of the People's Republic of China which was first passed in 2000. Specifically, the Bureau of Radio Regulation (also known as the State Radio Office) under the Ministry of Industry and Information Technology (MIIT) is a specialised technical agency in charge of radio monitoring and radio spectrum management. Its key responsibilities include:

- to draw up the planning of radio spectrum
- to allocate, allot and assign radio frequency
- to supervise and regulate the radio stations in accordance with the law
- to deal with radio monitoring, testing, radio interference investigations
- to organise and implement radio control in accordance with the law.

C.2.1 Background on spectrum management

Primary awards of spectrum

According to Telecommunications Regulations of the People's Republic of China, the State shall carry out uniform planning, centralised administration and reasonable allocation and shall implement a system of use with compensation with respect to telecoms resources, which includes radio frequencies, satellite orbit locations, telecoms network codes, etc.[162]

161 Source: MIC (October 2012), Revised Action Plan for Spectrum Reallocation.

162 Retrieved from http://www.china.org.cn/business/laws_regulations/2010-01/20/content_19273945_4.htm.

Historically, MIIT has assigned multiple spectrum using the administratively assigned approach, which is summarised in Figure C.1.

Figure C.1: Spectrum assignment in Mainland China [Source: MIIT, 2017]

Band	Operator	Usage
800MHz	China Telecom	CDMA/LTE FDD
900MHz	China Mobile	GSM900
900MHz	China Unicom	GSM900/WCDMA/LTE FDD
1900/2300/2500MHz	China Mobile	First release of 4G spectrum (LTE TDD)
2300/2500MHz	China Unicom	First release of 4G spectrum (LTE TDD)
2300/2500MHz	China Telecom	First release of 4G spectrum (LTE TDD)
1800MHz	China Unicom	Second release of 4G spectrum (LTE FDD)
1800MHz	China Telecom	Second release of 4G spectrum (LTE FDD)

Generally, before assignment, temporary spectrum is given to operators to conduct trials in a smaller region to verify the feasibility of the technology (as demonstrated for both the TDD and FDD spectrum released for 4G). Then, operators need to submit their application for new spectrum assignment. The Bureau of Radio Regulation will review the application and decide whether new spectrum will be released. No auction or beauty contest will be held for the spectrum assignment.

Extent of spectrum reassignment permitted

No spectrum trading regime has been established in Mainland China. According to Telecommunications Regulations of the People's Republic of China, without the approval of the supervisory department for the information industry under the State Council or the telecoms administration authority of the province, autonomous region or municipality directly under the central government, the operator may not unilaterally use, transfer or lease out telecoms resources or change the use of telecoms resources.

Since the spectrum is assigned through administrative assignment and thus no winning prices are paid upfront, the regulator has the rights, given by the law, to adjust spectrum assignment or take back assigned spectrum after negotiation with the assignees. In this way, re-assignment of spectrum can be achieved.

As an example, 1.9GHz spectrum was previously assigned to China Unicom and China Telecom for PHS. After PHS exited the market in 2011, MIIT decided that the same spectrum was to be assigned for 4G. China Unicom and China Telecom returned the spectrum, which was re-assigned to China Mobile in 2013.

C.2.2 Analysis of the current mechanism on spectrum reassignment

Up till now, spectrum in Mainland China is still assigned through administrative assignment. Compared to auction, administrative assignment is less transparent and may deviate from market trend. However, under the current regulatory framework, the regulator also has the right to review the spectrum usage and revoke spectrum if it is not used efficiently. According to Li Hengshuai,[163] Head of the Frequency Planning Division in the Bureau of Radio Regulation, the regulator is planning to establish a dynamic spectrum assignment mechanism to improve the usage efficiency. Moreover, the regulator is also considering having regular review of the assigned spectrum and call back spectrum that is underutilised or assigned for outdated technologies. All these measures will help to achieve an efficient usage of the scarce spectrum resource.

Moreover, a great amount of spectrum has been reserved by the regulator which could potentially be cleared for mobile operators. When new demand arises, major operators in Mainland China which are all state-owned, can submit applications to ask for new spectrum release, which also reduces the demand for spectrum trading.

163 Retrieved from http://www.mscbsc.com/viewnews-111316.html.

Annex D Impact assessment of spectrum trading on market outcomes

In this section, we conduct a basic qualitative and quantitative analysis to check for evidence of the impact of spectrum trading on the revenues from primary awards and prices in downstream markets across our case study countries. Our quantitative analysis focuses on countries in Category 1, making use of the fact the clear spectrum trading regimes have been introduced at different points in time, which provides us with the opportunity to use data for these different countries covering a period of time before and after the introduction of trading regimes for our analysis.

D.1 Revenue from primary awards

We use data covering 59 major auctions held in six countries (in which a spectrum trading regime was introduced and where auctions have been used for primary spectrum awards) between 1994 and 2016[164] in order to examine whether the introduction of a trading regime has had an effect on the prices paid for spectrum licences in primary awards (i.e. auctions). On top of category 1 countries, Ireland has been included in this econometric study. This is to ensure that the proportion of auctions (in the dataset used in the econometric model) that were conducted in the absence of a trading regime is not insignificant. This is necessary in order to derive meaningful results from the analysis.

This analysis is complicated by the fact that revenues depend on a large number of factors, and in order to establish whether the introduction of a trading regime has affected revenues generated from primary awards, we will need to control for the impact of these factors.

From theoretical considerations, we expect the revenue from primary awards (the dependent variable in our model) to be affected by factors that fall into the following categories:

- **Auction-specific factors**, such as the competitiveness in the auction; this is represented in our model by the total number of bidders that participated in the auction.
- **Country-specific factors**, which are constant for a particular country over time and which affect costs and prospective revenues, such as average level (over the time-period covered by the model) of population density, urbanisation or per capita income, and land-area.

164 The data is taken from DotEcon's Spectrum Auction Database. The countries considered are the five Category 1 countries (USA, Canada, New Zealand, UK, and Australia), plus Ireland which is included to provide additional data points, and was considered appropriate given its similarities to the other countries in that a clear spectrum trading regime has been introduced there and auctions have been used as the primary method for awarding spectrum for a number of years.

- **Time-specific factors** – which are constant across all countries for a given time period, but vary over time, such as equipment availability, general appetite for new technologies.

To estimate the impact of the introduction of a trading regime on revenues from primary awards, we use the following multiple regression 'fixed-effects' model for panel data:[165]

$$\log(REVENUE_{ij}) = \beta_1 \cdot \log(NUMBER_{ij}) + \beta_2 \cdot \log(TRADING_{ij}) + \beta_3 \cdot YEAR_{1996-1997} + \cdots\cdots + \beta_{13} \cdot YEAR_{2016-2017} + \sum_{i=1}^{5} \beta_{i+13} \cdot \mu_i + \epsilon_{ij}$$

Where:

- $REVENUE_{ij}$ is the average of the licence prices per MHz per capita paid in an auction in country i and time period j (where time-periods in our analysis refer to quarter-years), expressed in US$ (in February 2017 terms).
- $NUMBER_{ij}$ is the number of bidders that participated in the auction in country *i* and time-period *j*; this variable is a metric for the competitiveness of the auction.
- $TRADING_{ij}$ is a dummy variable that is set to 1 if a trading regime exists in country i at time-period j, and 0 otherwise.
- the $YEAR$ variables are time dummy variables (also called time fixed-effects), set to 1 for time periods that lie within the interval specified in the subscript and 0 otherwise, e.g. $YEAR_{1996-1997}$ is set to 1 if and only if time-period j lies in the time interval between Q1 1996 and Q4 1997 (inclusive of Q1 1996 and Q4 1997); these variables help us account for time-trends in auction revenues, i.e. time-specific factors.
- μ_i is the country dummy variable (also called country fixed-effect) for country *i*, set to 1 for auctions conducted in country *i*, and 0 otherwise; this variable helps us account for the unique characteristics of country *i* that have an impact on auction revenues, i.e. country-specific factors.
- ϵ_{ij} is the error-term capturing any variation in the dependent variable (i.e. $REVENUE_{ij}$) that is not accounted for by the control variables (i.e. $NUMBER_{ij}$ and $TRADING_{ij}$), country fixed-effects (i.e. μ_i's) and time fixed-effects (i.e. $YEAR$'s).

Figure D.2 provides the summary statistics for each of these variables.

Figure D.2: Summary statistics [Source: GSMA, 2017]

Variable	No. of observations	Mean	Standard deviation	Min.	Max.
$REVENUE_{ij}$	59	0.63	1.34	0.0000105	6.86

165 See Jeffery Wooldridge, Introduction to Econometrics, Cengage Learning UK 2013, pp. 485-486.

Variable	No. of observations	Mean	Standard deviation	Min.	Max.
$NUMBER_{ij}$	59	24.56	43.61	1	255
$TRADING_{ij}$	59	0.68	0.47	0	1
$YEAR_{1996–1997}$	59	0.05	0.22	0	1
$YEAR_{1998–1999}$	59	0.12	0.33	0	1
$YEAR_{2000–2001}$	59	0.19	0.39	0	1
$YEAR_{2002–2003}$	59	0.08	0.28	0	1
$YEAR_{2004–2005}$	59	0.10	0.30	0	1
$YEAR_{2006–2007}$	59	0.08	0.28	0	1
$YEAR_{2008–2009}$	59	0.15	0.36	0	1
$YEAR_{2010–2011}$	59	0.02	0.13	0	1
$YEAR_{2012–2013}$	59	0.05	0.22	0	1
$YEAR_{2014–2015}$	59	0.08	0.28	0	1
$YEAR_{2016–2017}$	59	0.02	0.13	0	1
μ_{Canada}	59	0.17	0.38	0	1
$\mu_{Ireland}$	59	0.07	0.25	0	1
$\mu_{New\ Zealand}$	59	0.07	0.25	0	1
μ_{UK}	59	0.15	0.36	0	1
μ_{USA}	59	0.37	0.49	0	1

Figure D.3 provides the full list of the awards used in the analysis.

Figure D.3: Auctions used in the analysis [Source: DotEcon, 2017]

Country	Name of auction	Auction completion date	Total revenue (USD cents per MHz per capita)	No. of bidders	$TRADING_{ij}$
USA	Auction 1 - Nationwide Narrowband (PCS)	29/07/1994	441.00	29	0
USA	Auction 3 - Regional Narrowband (PCS)	10/11/1994	685.53	28	0
USA	Auction 4 - Broadband PCS A and B Block	13/03/1995	70.93	30	0
USA	Auction 5 - Broadband PCS C Block	06/05/1996	161.29	255	0
USA	Auction 10 - PCS C Block	16/07/1996	321.56	32	0
USA	Auction 11 - Broadband PCS D and E & F Block	14/01/1997	44.92	153	0
USA	Auction 17 - Local Multipoint Distribution System	25/03/1998	0.44	139	0
Australia	PCS 800MHz–1800MHz auction	20/04/1998	13.46	9	1
Australia	BWA 28–31GHz Auction	18/02/1999	0.09	5	1

Country	Name of auction	Auction completion date	Total revenue (USD cents per MHz per capita)	No. of bidders	$TRADING_{ij}$
US	Auction 22 - C and D and E and F Block Broadband PCS	15/04/1999	13.76	67	0
Australia	PCS 3rd auction 800MHz	03/05/1999	1.88	1	1
Canada	24 & 38GHz Auction	19/11/1999	0.19	13	1
USA	Auction 23 - LMDS Re-Auction	05/12/1999	0.57	90	0
Australia	PCS 2000 auction	15/03/2000	143.89	7	1
UK	3G Auction	27/04/2000	551.07	13	0
Australia	3.4GHz Auction	24/10/2000	4.33	9	1
UK	BFWA 28GHz Auction	20/11/2000	0.39	7	0
Australia	BWA 27GHz Auction	28/11/2000	0.34	2	1
New Zealand	Auction 3: 1710–2300MHz	18/01/2001	9.63	7	1
USA	Auction 35 - C and F Block Broadband PCS	26/01/2001	294.86	87	0
Canada	Additional PCS Auction	01/02/2001	50.35	7	1
USA	Auction 38 - Upper Guard bands	21/02/2001	55.47	5	0
Australia	3G Auction	22/03/2001	78.44	6	1
USA	Auction 41 Narrowband PCS	18/10/2001	4.54	9	0
New Zealand	Auction 5 WLL and LMP and Cellular	01/08/2002	0.92	4	1
USA	Auction 49 - Lower 700MHz band	13/06/2003	4.73	56	1
UK	PFWA 3.4GHz Auction	17/06/2003	0.82	13	0
USA	Auction 51 Regional Narrowband PCS	25/09/2003	0.26	2	1
USA	Auction 50 Narrowband PCS	29/09/2003	4.03	4	1
Canada	2300 & 3500MHz Auction	16/02/2004	0.17	22	1
USA	Auction 56–24GHz Service	28/07/2004	0.04	3	1
Canada	Residual 2300 & 3500MHz Auction	27/01/2005	1.29	25	1
USA	Auction 58 - Broadband PCS	15/02/2005	76.11	35	1
USA	Auction 60 - Lower 700MHz band Auction	26/07/2005	17.16	5	1
Ireland	WDM Auction	21/12/2005	1.10	4	0
Australia	3.4GHz Auction 2 Round 11	13/09/2006	1.50	1	1
Ireland	1785–1805MHz	27/04/2007	0.34	2	0
UK	1785–1805MHz	09/05/2007	1.76	2	1
US	Auction 71 - Broadband PCS	21/05/2007	29.46	23	1
New Zealand	2.3 and 2.5GHz auction	18/12/2007	0.41	10	1

Country	Name of auction	Auction completion date	Total revenue (USD cents per MHz per capita)	No. of bidders	$TRADING_{ij}$
UK	UK 10–40GHz	22/02/2008	0.001	10	1
UK	UK L band	21/05/2008	0.74	8	1
Canada	AWS auction	27/05/2008	85.35	27	1
Ireland	Irish 26GHz award	06/06/2008	0.04	5	0
USA	Auction 78 - Broadband PCS	20/08/2008	24.10	23	1
UK	Interleaved spectrum auction	05/02/2009	0.09	1	1
UK	Interleaved spectrum auction	27/02/2009	0.31	1	1
Canada	Auction of spectrum for air-ground services	25/05/2009	1.65	3	1
Canada	Residual Spectrum Licences in the 2300MHz and 3500MHz bands	30/06/2009	0.96	9	1
USA	Auction 92–700MHz band	25/07/2011	58.42	19	1
Ireland	Irish Multiband Auction	15/11/2012	44.76	4	0
UK	UK 4G Auction	20/02/2013	33.78	7	1
Australia	Australia 4G auction	07/05/2013	23.09	3	1
New Zealand	New Zealand 700MHz	22/01/2014	60.17	3	1
Canada	Canada 700MHz	13/02/2014	59.08	10	1
US	Auction 97- AWS-3	29/01/2015	95.47	70	1
Canada	Canada AWS-3	03/03/2015	79.59	10	1
Canada	Canada 2.5GHz	12/05/2015	14.95	11	1
Australia	Australia 1800MHz	04/02/2016	47.51	4	1

The regression results from our model are shown in Figure D.4.

Figure D.4: Results from the fixed-effects linear regression [Source: DotEcon]

	Dependent variable			Implied change in $REVENUE_{ij}$
	$\log(REVENUE_{ij})$	p-value[166]	Standard errors[167]	
$\log(NUMBER_{ij})$	0.466*	0.01	0.181	+0.46%
$TRADING_{ij}$	0.0374	0.96	0.668	+3.81%
$YEAR_{1996-1997}$	– 1.35***	< 10-5	0.237	– 74.08%

166 A p-value is used to quantify the idea of statistical significance of evidence, and is defined as the probability, under the null hypothesis, of obtaining a result equal to or more extreme than what was actually observed. A large p-value provides evidence to support the null hypothesis, i.e. the variable is not statistically significant; while a small p-value (less than 0.05) suggests that the null hypothesis can be rejected, i.e. the variable is of statistical significance.

167 The residuals in our model do not exhibit any heteroskedasticity or serial-correlation. However, as per the commonly followed practice in econometrics (see for example Wooldridge, 2013, pp. 273-274), we have used standard errors robust to both of these effects in deriving the statistical significance of coefficients in our model.

	Dependent variable			Implied change in $REVENUE_{ij}$
	$\log(REVENUE_{ij})$	p-value[166]	Standard errors[167]	
$YEAR_{1998-1999}$	– 5.08***	< 10-5	0.652	– 99.38%
$YEAR_{2000-2001}$	– 1.44**	0.007	0.509	– 76.31%
$YEAR_{2002-2003}$	– 4.14***	< 10-5	0.608	– 98.41%
$YEAR_{2004-2005}$	– 4.27***	< 10-5	0.490	– 98.60%
$YEAR_{2006-2007}$	– 3.16***	< 10-3	0.777	– 95.76%
$YEAR_{2008-2009}$	– 4.30***	< 10-3	1.02	– 98.64%
$YEAR_{2010-2011}$	– 1.40*	0.03	0.605	– 75.34%
$YEAR_{2012-2013}$	0.128	0.89	0.884	– 13.66%
$YEAR_{2014-2015}$	– 0.728	0.23	0.594	– 51.71%
$YEAR_{2016-2017}$	– 0.427	0.31	0.416	– 34.75%
$\mu_{Cananda}$	– 0.08	0.94	1.09	– 7.69%
$\mu_{Ireland}$	– 1.38	0.36	1.49	– 74.84%
$\mu_{New\ Zealand}$	– 0.71	0.59	1.32	– 50.84%
μ_{UK}	– 1.50	0.21	1.17	– 77.69%
μ_{USA}	0.45	0.60	0.86	56.83%
Observations 59				
R-squared 0.59				
Significance codes: '***' for p-value < 0.001; '**' for p- value < 0.01; '*' for p-value < 0.05;				

Diagnostic tests

The quality of estimation (of the value of the coefficients) and inference (of the statistical significance of the coefficients) in our model are reliant on the data set being used respecting certain theoretical requirements. These requirements include:

- **Absence of heteroskedasticity and serial-correlation** – a Breusch-Godfrey test for serial-correlation in panel data and a Breusch-Pagan test for heteroskedasticity in panel data reveals that the model is free from heteroskedasticity and serial-correlation.[168]
- **Normality of the error terms (ϵ_{ij})** – Figure D.5 shows a plot of the quantiles of the residuals in our model versus the theoretical quantiles of the normal distribution. It reveals a linear trend, which is confirmed by the correlation coefficient between the two quantities (0.99), suggesting

168 The value of the Breusch-Pagan test statistic is 11.43 (p-value = 0.57), which is below the 95% critical value of a χ^2distribution with 13 degrees of freedom, 22.36. The value of the Breusch-Godfrey test statistic is 3.85 (p-value = 0.43), which is below the 95% critical value of a χ^2distribution with 4 degrees of freedom, 9.49.

that the error terms are normally distributed and that therefore the assumption of normality of the error terms holds.

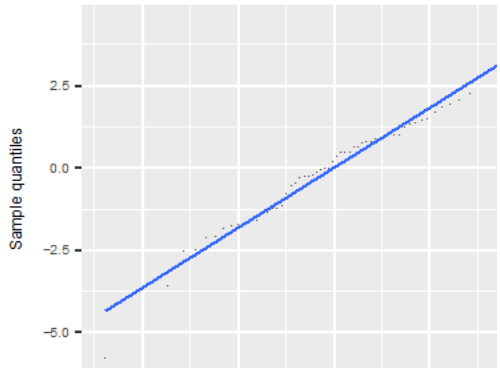


Figure D.5: Plot of sample quantiles (of the residuals in our model) versus the theoretical quantiles of the normal distribution

Discussion of results

The coefficient for $NUMBER_{ij}$ is positive and is statistically significant, suggesting the competitiveness of an auction has a positive effect on revenue from primary awards. Out of the 11 time dummy variables[169] in our model, only 3 are statistically insignificant, indicating the presence of time trends in spectrum prices.[170] This is consistent with theoretical expectations. The estimation suggests that there is some variation in prices due to country-specific factors, however none of the country dummy variables[171] are statistically significant, so we cannot form any strong conclusions in that regard.

The value of the coefficient for $TRADING_{ij}$ implies that the per MHz per capita prices paid for spectrum licences have increased by less than 4% as a result of the introduction of spectrum trading regimes. Unlike the other variables ($NUMBER_{ij}, YEAR$), the coefficient for $TRADING_{ij}$ is not statistically significant at the 95% significance level. Therefore, our analysis does not provide any conclusive evidence of a relationship between the introduction of a spectrum trading regime and prices paid for licences, owing to the coefficient for $TRADING_{ij}$ being neither statistically significant, nor significant in magnitude.

---

169 The change in $REVENUE_{ij}$ implied by time dummy variables *YEAR*'s is relative to the base time-period 1994-1995. For example, the coefficient of $YEAR_{2016–2017}$ implies that the (per MHz per capita) prices paid for licences in auctions held in the years between 2016-2017 decreased by 34.75% relative to the prices paid in auctions between the years 1994-1995 (all other factors being equal).

170 The 2017 GSMA report on "Effective Spectrum Pricing" notes that there was a sharp global decline in the (per MHz per capita) spectrum licence prices in the period 2004-2008 after the "tech bubble" – which generated huge enthusiasm for 3G services – faded. The sharp decrease in the value of the coefficients for $YEAR_{2002–2003}$, $YEAR_{2004–2005}$, $YEAR_{2006–2007}$ and $YEAR_{2008–2009}$, relative to the value of the coefficient for $YEAR_{2000–2001}$, reflects this trend.

The GSMA report further notes that the arrival of 4G technology led to a global growth rebound in per MHz per capita spectrum licence prices beginning in the year 2008. This trend is consistent with the increase in the value of the coefficients for $YEAR_{2010–2011}$, $YEAR_{2012\_2013}$, $YEAR_{2014–2015}$ and $YEAR_{2016–2017}$, relative to the coefficient for $YEAR_{2008–2009}$.

171 The change in $REVENUE_{ij}$ implied by the country dummy variables μ_i is relative to the base country Australia (alphabetically the first country amongst the group of countries used in our model). For example, the coefficient of μ_{USA} implies that the (per MHz per capita) prices paid for licences in auctions held in the USA are 56.83% higher than in auctions held in Australia (all other factors being equal).

D.2 Prices in the downstream market

We use quarterly data on 'average revenue per user' (ARPU) and market concentration[172] covering the period from 2000 to 2017 in order to examine whether the introduction of a trading regime has had an effect on prices in the downstream mobile telecoms services market. Again, we use an econometric model in order to control for the impact of other factors on ARPU (the dependent variable in our model). These include:

- **Country-specific factors**, which are constant for a particular country over time – such as average level (over the time-period covered by the model) of population density, urbanisation or income, and land-area – which affect costs and thus prices.

- **Time-specific factors**, which are constant across all countries for a given time period, but vary over time, such as changes in service quality or cost reductions over time as technology develops.

- **The market structure in the downstream market**, which we proxy using the Herfindahl-Hirschman Index (HHI) as a measure of concentration.[173] Assuming that higher levels of concentration imply less competition (all other things being equal) and that prices in less competitive markets are higher, we would expect ARPUs and HHIs to be positively correlated.

We expect that, based on theoretical considerations, spectrum trading might have an impact on prices through its impact on competition. Specifically, spectrum trading might affect both market structure and conduct of market players:[174]

- First, spectrum trading might result in new entry or facilitate expansion, thereby reducing market concentration and lowering the HHI, but it could also result in spectrum hoarding, which might have the opposite effect of making markets more concentrated (i.e. increasing the HHI).

---

172 Source: GSMA Intelligence 2017.

173 The Herfindahl-Hirschman Index is calculated by taking the sum of the squares of the percentage market share (by revenue) of major operators in the telecoms market of a country. The theoretical range of the index is between 0 and 10,000, with 0 representing an infinite number of firms with non-zero market share operating in the market, and 10,000 indicating a single operator with 100% of the market-share.

174 The relationship between market structure, conduct of market players and market outcomes is complex and has been the subject of much debate amongst competition economists. The simple presumption that market structure determines conduct and thus market performance has been shown to be wrong, but at the same time market structure remains an important indicator of competitiveness. The complexity arises from the fact that there are many factors beyond the number and share of competitors that affect competition (such as the absence of barriers to entry, as demonstrated in the theoretical reference model of perfectly contestable markets, where market structure is entirely irrelevant), and the fact that market structure is endogenous and affected by the behaviour of market players. For a small sample of the relevant literature on the link between market structure and competitiveness see:

- Bain, J S, 1951, 'Relation of Profit Rate to Industry Concentration: American Manufacturing, 1936–1940', *Quarterly Journal of Economics* Vol 65(3), pp 293–324.
- Cowling, K and M Waterson, 1976, 'Price-Cost Margins and Market Structure', *Economic Journal* Vol 43, pp 267–274.
- Baumol, W J, 1982, 'Contestable Markets: An Uprising in the Theory of Industry Structure', *The American Economic Review* Vol 72, pp 1-15.
- Tirole, J, 1988, *The theory of industrial organization*, Cambridge: MIT Press, pp 221-223.

- Second, even without changes in market structure, the presence or absence of trading opportunities could affect behaviour. For example, the existence of a trading regime might create sufficiently strong incentives for existing operators to lower prices in anticipation of new operators entering the market (by obtaining spectrum on the secondary market), potentially even trying to discourage such entry.[175] In this case, spectrum trading would lead to a decrease in prices without a corresponding change in the market concentration.

In practice, it is not possible to disentangle these two effects. They might occur in parallel, and reinforce or cancel each other. Some competition effects may be captured in changes in concentration, whilst others might not be.

This makes our use of the HHI as an indicator alongside a dummy variable for spectrum trading as independent variables potentially problematic. At the same time, we need a way to correct for differences in competitiveness across markets and time that are unrelated to spectrum trading in order to identify whether trading has a price impact, and the HHI proxy would seem to be a suitable candidate.

In order to address this problem, we use a two-stage approach where we first look at whether there is an impact from trading on market concentration, which would suggest that the HHI could not be used to correct for competition effects that are not related to trading.

► *Relationship between spectrum trading and HHI*

In a model that is used to study the relationship between ARPU and the introduction of a trading regime, it is important to include HHI as an independent variable, as the level of competition in the market is a significant factor in determining prices. However, if there is a significant relationship between the presence of a trading regime and market concentration including HHI as an independent variable could limit the extent to which the model indicates the full impact of spectrum trading on ARPU. In order to ensure that the HHI does not mask some of the impact of trading on ARPU, we check as a first step whether there is any relationship between spectrum trading and the HHI using the following multiple regression fixed effects model:

$$HHI_{ij} = \beta_1 \cdot TRADING_{ij} + \sum_{i=1}^{5} \beta_{i+1} \cdot \mu_i + \sum_{j=1}^{68} \beta_{j+6} \cdot \eta_j + \epsilon_{ij}$$

175 Of course, as the analysis of entry-deterrence models show, it is the post-entry behaviour of market players that matters for the decisions of potential entrants, and cutting prices to prevent entry is ineffective if entrants can expect the rational response post entry to be for existing market players to accommodate. For an overview of the entry-deterrence literature, see Tirole, J, 1988, *The theory of industrial organization*, Cambridge: MIT Press, chapter 8.

Where:

- HHI_{ij} is the Herfindahl-Hirschman Index of the telecoms market in country i and time period j (where time-periods in our analysis refer to quarter-years).
- $TRADING_{ij}$ is a dummy variable that is set to 1 if a trading regime exists in country i at time-period j, and 0 otherwise.
- η_j is the dummy variable for time period j (also called time fixed-effect), set to 1 for time period j and 0 otherwise; these variables help us account for time-trends in ARPU, i.e. time-specific factors.
- μ_i is the dummy variable for country i (also called country fixed-effect), set to 1 for country i and 0 otherwise; this variable helps us account for the unique characteristics of country i that have an impact on ARPU, i.e. country-specific factors.
- ϵ_{ij} is the error-term capturing any variation in the dependent variable (i.e. HHI_{ij}) that is not accounted for by the control variable (i.e. $TRADING_{ij}$), country fixed-effects (i.e. μ_i's) and time fixed-effects (i.e. η_j's).

Figure D.6 provides the summary statistics for each of these variables.

Figure D.6: Summary statistics [Source: GSMA, 2017]

Variable	No. of observations	Mean	Standard Deviation	Min.	Max.
HHI_{ij}	414	3184	978	1033	5517
$TRADING_{ij}$	414	0.79	0.41	0	1
μ_{Canada}	414	0.17	0.37	0	1
$\mu_{Ireland}$	414	0.17	0.37	0	1
$\mu_{New\ Zealand}$	414	0.17	0.37	0	1
μ_{UK}	414	0.17	0.37	0	1
μ_{USA}	414	0.17	0.37	0	1

The regression results are shown below in Figure D.7.

Figure D.7: Results from the fixed-effects linear regression[176] [177] [Source: DotEcon]

	Dependent variable			Implied change in HHI_{ij}
	$\log(HHI_{ij})$	p-value	Standard Errors[178]	
$TRADINGR_{ij}$	364	0.20	282	+364
Observations	414			
R-squared	0.77			
Significance codes: '***' for p-value < 0.001; '**' for p- value < 0.01; '*' for p-value < 0.05				

The results of our analysis indicate that there is no clear relationship between spectrum trading and HHI levels. However, the model assumes that any impact of the introduction of a spectrum trading regime on market concentration would be instantaneous. This is reflected by the fact that the market concentration in period j (HHI_{ij}) is assumed to be proportional to the value of the trading dummy variable in period j ($TRADING_{ij}$). However, it is possible (and indeed likely) that there would be some delay between the introduction of spectrum trading and any impact on market concentration. To test this, we use the same model as before, but assume that the market concentration in period j is proportional to the value of trading dummy variable in period $j-4$ (i.e. the effect of the trading regimes is felt in the markets after four periods, which is equal to one year). This gives the following modified model:

$$HHI_{ij} = \beta_1 \cdot TRADING_{i,j-4} + \sum_{i=1}^{5} \beta_{i+1} \cdot \mu_i + \sum_{j=1}^{68} \beta_{j+6} \cdot \eta_j + \epsilon_{ij}$$

Introducing a lag in the model makes the coefficient of the trading dummy statistically significant. However, further analysis suggests that this result is unlikely to be valid. In the US, a year after the introduction of a trading regime there was a sharp increase in merger and acquisition activity in the telecoms sector (the acquisition of AT&T Wireless by Cingular in Q4 2004 and that of Nextel by Sprint in Q3 2005). Therefore, whilst it was the M&A activity that caused the spike in HHI_{ij} observed in the US at that time, this would probably have been picked up in the model as a result of the trading regime. If we run the modified model (i.e. with the trading dummy variable lagged by

176 Diagnostic tests to check the assumptions of the fixed-effects linear model were conducted to assess the quality of the estimation and statistical inference in the model. The Breusch-Godfrey test in panel data revealed the presence of serial-correlation in the data, and the Breusch-Pagan test for panel data revealed the presence of heteroskedasticity in the data. Therefore, the standard-errors used for statistical inference (reported in Figure D.6) are robust to the presence of serial-correlation and heteroskedasticity in the data. The plot of the quantiles of the residuals in our model versus the theoretical quantiles of the normal distribution revealed a linear trend, which was confirmed by the correlation coefficient between the two quantities (0.99). Therefore, we can safely assume that the error-terms ϵ_{ij} in our model follow the normal distribution.

177 Although the country and time dummy variables are present in the model, the estimated values of their coefficients have not been displayed, as there are 73 of them.

178 Heteroskedasticity and serial-correlation robust standard errors.

four time-periods) but without the data for the USA, we find that the coefficient for the (lagged) trading dummy is insignificant. The results are shown in Figure D.8.

Figure D.8: Results from the fixed-effects linear regression [Source: DotEcon]

	Dependent variable			Implied change in HHI_{ij}
	$\log(HHI_{ij})$	p-value	Standard Errors[179]	
$TRANSFER_{i,j-4}$	331	0.21	266	+331
Observations	325			
R-squared	0.76			
Significance codes: '***' for p-value < 0.001; '**' for p- value < 0.01; '*' for p-value < 0.05				

► *Impact of spectrum trading on ARPU*

Based on the above analysis, we find that there is no clear evidence to suggest the introduction of spectrum trading has had an impact on market concentration, and we can include the HHI as an independent variable in our ARPU model to capture competition effects of trading that are not related to changes in concentration. Our model is as follows:

$$\log(ARPU_{ij}) = \beta_1 \cdot HHI_{ij} + \beta_2 \cdot TRADING_{ij} + \sum_{i=1}^{5} \beta_{i+2} \cdot \mu_i + \sum_{j=1}^{68} \beta_{j+7} \cdot \eta_j + \epsilon_{ij}$$

Where:

- $ARPU_{ij}$ is the average revenue per user (ARPU) in country *i* and time-period *j*; and
- all other variables are as defined above.

Figure D.9 shows the summary statistics for the variable $ARPU_{ij}$.

Figure D.9: Summary statistics for $ARPU_{ij}$ [Source: DotEcon]

Variable	No. of observations	Mean	Standard Deviation	Min.	Max.
$ARPU_{ij}$	414	44.65	13.91	18.98	93.58

179 Heteroskedasticity and serial-correlation robust standard errors.

The results of the analysis are shown in Figure D.10.

Figure D.10: Selected results from the fixed-effects linear regression model[180] [Source: DotEcon]

	Dependent variable			Implied change in $ARPU_{ij}$
	$\log(ARPU_{ij})$	p-value	Standard Errors[181]	
HHI_{ij}	0.0000982**	0. 002	0.0000307	+0.00982%
$TRANSFER_{ij}$	– 0.0900	0.22	0.0740	– 8.61%
Observations	414			
R-squared	0.92			
Significance codes: '***' for p-value < 0.001; '**' for p- value < 0.01; '*' for p-value < 0.05				

Diagnostic tests

The quality of estimation (of the value of the coefficients) and inference (of the statistical significance of the coefficients) in our model are reliant on the data set being used respecting certain theoretical requirements. The requirements include:

- **Absence of heteroskedasticity and serial-correlation** – a Breusch-Godfrey test for serial-correlation in panel data and a Breusch-Pagan test for heteroskedasticity in panel data reveals that the model is free from heteroskedasticity, although there could be serial-correlation present.[182] We therefore use serial-correlation (and heteroskedasticity) robust standard errors for statistical inference in our model.

- **Normality of the error terms (ϵ_{ij})** – Figure D.11 shows a plot of the quantiles of the residuals in our model versus the theoretical quantiles of the normal distribution. It reveals a linear trend, which is confirmed by the correlation coefficient between the two quantities (0.99), suggesting that the error terms are normally distributed and that the assumption of normality of the error terms holds.

180 Although the country and time dummy variables are present in the model, the estimated values of their coefficients have not been displayed.

181 Heteroskedasticity and serial-correlation robust standard errors.

182 The value of the Breusch-Pagan test statistic is 2.77 (p-value = 0.25), which is below the 95% critical value of a χ^2distribution with 2 degrees of freedom, 5.99. The value of the Breusch-Godfrey test statistic is 374 (p-value < 0.0001), which is above the 95% critical value of a χ^2distribution with 69 degrees of freedom, 89.39.

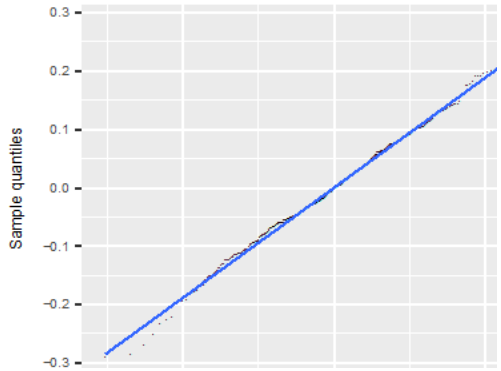


Figure D.11: Plot of sample quantiles (of the residuals in our model) versus the theoretical quantiles of the normal distribution [Source: DotEcon]

Discussion of results

The estimated coefficient of the control variable HHI_{ij} (in Figure D.10) is statistically significant and positive, which is consistent with the theoretical expectation that prices are affected by the level of competition in the market.

The results of our analysis suggest that the introduction of spectrum trading regimes has a negative impact on ARPU, which is consistent with the view that having a trading regime in place creates pressure on operators to charge lower price to pre-empt new market entry. However, this effect is not statistically significant (especially when compared to the effects of market concentration) and so the analysis does not provide any conclusive evidence of a relationship between spectrum trading and ARPU.

Annex E Questions for industry interviews

4. What benefits would spectrum trading bring to consumers, businesses and users of spectrum? Are there specific challenges in the market which you think that spectrum trading can help to resolve?

5. What costs would spectrum trading bring to consumers, businesses and users of spectrum? Are there specific issues or problems which you think might arise from the implementation of spectrum trading?

6. If spectrum trading is to be introduced in Hong Kong:

    a. what particular types of transfer of rights to use radio spectrum (full, leasing, partial etc.) do you consider as being beneficial? Why or why not?
    b. [for MNOs] do you have plan to purchase/lease spectrum, and would you be willing to sell spectrum to other operators?
    c. [for MVNOs] do you have plan to purchase/lease spectrum and build network on your own, or would you prefer continuing to lease network capacities from MNOs?

7. If spectrum trading is not introduced in Hong Kong in the short- to medium-term (i.e. next five to ten years), do you envisage any problems or difficulties in respect to your operation?

8. In 2012 and 2016, the CA approved respectively two requests for frequency swaps between MNOs (between CMHK and SmarTone in the 1800MHz band in 2012; as well as between CMHK and HKT in the 2600MHz band in 2016) after taking into consideration a list of relevant factors. How would you compare requests for frequency swap subject to the CA's approval on a case-by-case basis with spectrum trading, taking into account the potential benefits and issues/problems that might arise from spectrum trading as discussed above?

9. Currently MVNOs may lease network capacity from MNOs to provide mobile services. How would you compare such arrangements under network capacity leasing to spectrum trading (including spectrum leasing)?

10. Based on your knowledge of the industry, if spectrum trading were to be in place in Hong Kong, would you expect there will be a lot of transactions? Why or why not?

11. Apart from spectrum trading, do you see other spectrum-related regulatory mechanisms which could enhance the efficient use of spectrum in Hong Kong?

12. Do you have any other comments related to spectrum trading?

13. If spectrum trading cannot be introduced, and if no radio spectrum in the sub-3GHz band is available in the short- to medium-term (i.e. next five to 10 years) in Hong Kong, to help tackle the problems and the difficulties that you envisaged (as mentioned in question 4.1), other than taking part vigorously in the forthcoming auction for more spectrum in the 900GHz/1800GHz spectrum, do you have other plans in mind?

Annex F Detailed responses of industry stakeholders

This annex presents detailed responses of selected industry representatives and includes their opinion on the following topics:

- expected benefits of spectrum trading
- potential costs of spectrum trading
- potential participation / demands for spectrum
- comments on alternative mechanisms to spectrum trading.

F.1 Expected benefits of spectrum trading

Industry players largely responded that spectrum trading is a tool that brings about flexibility to reassign spectrum outside of the primary assignment, and potentially lead to better spectrum utilisation.

Specifically, it could potentially resolve both specific and generic challenges in the market, including:

Specific bands
- Rejuvenate spectrum regarded by operators as underutilised.
- Correct 'outdated' spectrum assignments resulting from changes in technology.
- Correct fragmentation of frequency blocks.

General benefits
- Facilitate divestment of non-strategic spectrum assets.
- Rebalance spectrum portfolio of MNOs.
- Increased flexibility in spectrum management.

Specific examples of benefits of spectrum trading

► *Rejuvenate underutilisation of spectrum*

Two operators have remarked that spectrum utilisation in Hong Kong is already high. Nonetheless, there are some instances where spectrum appear underutilised (e.g. 2.3GHz, 600MHz and 850MHz bands). However, Analysys Mason notes that spectrum in the 600MHz band is mainly assigned for mobile TV use, hence might not be relevant for the purposes of this study; whereas spectrum in the 850MHz band were specifically assigned for Code Division Multiple Access 2000 (CDMA2000) in 2007 with the policy objective of strengthening Hong Kong's strategic position as a world city and the gateway between the Mainland of China.

In such instances, trading can facilitate the reassignment of spectrum to better use before expiry of the spectrum permission. However, two operators noted that there are other tools, aside from spectrum trading, that can be used to similar effect.

- *Correct outdated spectrum assignments resulting from changes in technology*

Three operators mentioned that spectrum assignment through market-based mechanisms like auctions, might over time, become inefficient or no longer represent global best practices. In such instances, spectrum trading can remedy "out-dated" and sub-optimal spectrum assignment, in a timely manner to maximise spectrum efficiency.

The example of spectrum in the 2.3GHz band was raised by three operators. This spectrum was previously auctioned in blocks of 30MHz in 2012, with three operators successfully bid for the spectrum. The block size of 30MHz may have limited the potential of MNOs to maximise capex efficiency for LTE deployment, which is technically most efficiently when deployed in blocks of 20MHz. An operator raised a potential spectrum trading scenario, where an operator could sell 10MHz of spectrum to another operator. If the spectrum sold is contiguous to the purchasing operator's spectrum holding, the purchaser could form a 40MHz continuous spectrum block, while the seller would retain 20MHz of spectrum. This revised assignment would result in a technically more efficient spectrum configuration, should both parties involved agree on such arrangement.

- *Correct fragmentation of frequency blocks*

Two operators have reported cases where primary assignment has led to fragmentation of frequency blocks. They believe that spectrum trading is a possible mechanism to allow an operator to aggregate spectrum holdings and provide services that will more efficiently use spectrum.

One example is in 900MHz and 1800MHz bands, which according to an interviewee contains several fragmented frequency blocks. In the 1800MHz band, lot sizes of 3.2MHz and 1.6MHz is held by 4 different operators. The operator interviewed believes that consolidation of such spectrum through spectrum trading will allow spectrum to be put to better use. Analysys Mason notes that the CA has decided to re-align the spectrum blocks to resolve issues regarding fragmentation of spectrum holdings in the next term of assignment commencing 2021. Auction for these frequency blocks is expected around the end of 2018.

General benefits of spectrum trading

Aside from specific bands where spectrum trading may facilitate the correction of existing spectrum inefficiencies, operators interviewed have also raised some general challenges in which they anticipate spectrum trading can help resolve.

- *Facilitate divestment of non-strategic spectrum assets*

An operator noted that spectrum holders may possess spectrum assets which they consider non-strategic to their operations but are unable to divest these assets due to the lack of exit mechanisms.

The operator felt that spectrum trading would allow operators to receive fair financial compensation when they sell spectrum assets that they deem non-strategic. This can be used when operators do not wish to swap the spectrum for any other frequency band, or when spectrum identified for

spectrum swap are of different valuations, such that monetary compensation is required to facilitate the spectrum exchange.

► *Rebalance spectrum portfolio of MNOs*

An operator remarked that there may be instances where market share changes substantially, which results in an MNO having insufficient spectrum to service its users, and another MNO with underutilised spectrum holdings. In such circumstances, spectrum trading provides a mechanism to rebalance spectrum portfolio between MNOs.

The operator remarked that spectrum trading allows one operator to transfer spectrum to another MNO who needs it more. This benefits the Hong Kong market as increased spectrum holdings will allow the MNO with increased market share to lower its deployment cost and pass down these cost savings to users. To achieve such benefits, the interviewee noted that spectrum trading should only be permitted between MNOs.

► *Increased flexibility in spectrum management*

An interviewee noted that spectrum trading will remove the need to wait for the next auction to obtain additional or offload excess capacity. Therefore, a benefit of spectrum trading is that it can be done any time, as and when needed.

Another operator also noted that spectrum trading might be more flexible than the current mechanism, as it allows one to acquire only spectrum assets previously owned by another company, whereas current mechanisms require M&A or setting up joint ventures prior to auctions to trade or share spectrum assets.[183]

F.2 Potential costs on spectrum trading

The implementation of a spectrum trading regime may introduce new problems to consumers, businesses and users of spectrum. Operators have also raised the following costs/risks if spectrum trading is allowed:

- spectrum speculation
- over-concentration of spectrum
- complications from management of spectrum already in the market / potential of windfall profit
- implementation complications.

183 Pre-auction arrangements to form a joint venture company to jointly bid for spectrum are permitted in Hong Kong. One example is Genius, a joint venture by Hutchison and HKT. However, after the auction, it is not possible to form partnerships with other licensees to share spectrum won in the auction. An operator remarked that this limits the flexibility of spectrum use.

Spectrum speculation

A common concern amongst operators interviewed was spectrum speculation, which some felt may be exacerbated if any party (not just MNOs) can trade commercial mobile spectrum. One MNO believed that public interest will be harmed if one party decides to hoard spectrum without intention of using the acquired spectrum. Three operators have opined that some spectrum has already been underutilised in the current non-spectrum trading regime; permitting spectrum trading might lead to more of such behaviour, and cause more inefficient use of spectrum. Another operator believes that the introduction of spectrum trading will lead to speculation and generate windfall gains for parties involved.

Although two MVNOs interviewed believe that spectrum trading will impact MNOs more, they also raised concerns about the potential of increased operating cost because of speculation on spectrum. There is concern that spectrum trading will cause interested parties to speculate on spectrum and increase price of spectrum. MNOs might pass on these price increases to MVNOs, thus increasing MVNO's cost of operations.

One safeguard raised by an operator against hoarding of spectrum for speculative activity is to restrict the opportunity to trade spectrum to existing MNOs only. This helps ensure that non-MNOs will not have the opportunity to hoard spectrum for speculative activity, and deny existing MNOs of sufficient spectrum to maintain their mobile services. Another operator remarked that if spectrum trading is introduced and there are windfall gains to be had, it should ideally be returned to the government.

Over-concentration of spectrum

Two operators highlighted that a potential cost of introducing spectrum trading is that it enables large players in the market to possess an over-concentration of spectrum, giving them stronger abilities to engage in anti-competitive behaviour. In particular, one operator raised concerns that it will be more difficult to compete and serve their customers under such circumstances.

Safeguards for such problems already exist, e.g. competition laws and guidelines by the Competition Authority, with one operator suggesting that potential anti-competitive trades can be identified through requiring ex-ante regulatory approval for all spectrum trades.

However, another operator highlighted that even though competition law exists, it is unclear how it will be applied if spectrum trading was to be introduced. The operator believed that there may be possibility for large players to acquire more spectrum, reducing competition in the market.

Complications from management of spectrum already in the market/potential of windfall gains and losses

An operator remarked that introduction of spectrum trading might result in complications in the management of spectrum already in the market.

For most operators, the availability of spectrum trading has not been factored in their decision to bid spectrum at primary assignments. Therefore, the operator remarked that if spectrum trading is introduced, conditions of the original spectrum licence might change, causing unexpected gains/ loss of market value of spectrum holdings relative to price paid at the point of assignment. Operators might seek compensation for such windfall losses, while there might be a public policy case to recoup windfall gains from operators who benefitted from the introduction of spectrum trading. Additional complications include the difficulties in quantifying these gains and losses.

Implementation complications

Implementation complications if spectrum trading is to be introduced were raised by two operators, as they believe it will introduce additional options and potentially introduce greater opportunity for speculation in the market.

The operators remarked that rules and regulations of not only the spectrum trading regime, but also auctions under the spectrum trading regime will have to be carefully considered to safeguard against concerns from spectrum trading. These include eligibility criteria for parties to be allowed to trade spectrum; transferability of obligations linked to the original spectrum licence (e.g. roll-out obligations); permissibility of change-of-use of spectrum; and development of service continuity regulation to ensure users are not impacted by spectrum changing hands.

On the other hand, one operator is of the opinion that spectrum trading, is consistent with the Government's Radio Spectrum Policy Framework and should be introduced as quickly as possible. It suggested the below framework as a guideline for implementation of spectrum trading:

- the current spectrum holder notifies the CA of its intention to trade
- the CA publishes the notified information
- if required, the CA reviews the transaction (e.g. to make sure it is not anti-competitive and does not cause interference issues)
- details of the final transaction are published.

F.3 Potential participation / demands for spectrum trading

Types of trades

Most operators interviewed do not have a strong opinion on what should or should not be allowed to trade. However, most agreed that dividing spectrum into regional permissions (location based partial rights) will not be practical in the Hong Kong context.

An operator that is strongly for the introduction of a spectrum trading regime, advocated support for all types of spectrum trading, and preferred to allow the market to determine the type of trades required.

Supply of spectrum for trading

Most MNOs have no concrete plans to participate in spectrum trading. Some operators mentioned that their decision to supply spectrum to the secondary market will be driven by individual business case, while others expressed need to understand the regime that will be implemented in Hong Kong to be able to make a more informed decision.

Demand for spectrum trading

- *MNO*

Likewise, most operators maintain a non-committal approach to their plans to purchase spectrum. One operator remarked that it will react per market forces, depending largely on its needs for spectrum and the expected price of the trade.

- *MVNO*

Two MVNOs interviewed were open to the possibility of acquiring spectrum, as some see spectrum trading as a potential way to be less reliant on MNOs. They noted that MNOs control their cost base. One MVNO noted that they will not need to rely on MNO to provide network capacity if they were able to acquire spectrum through trading. However, the MVNO noted that their business strategy as an MVNO is to be asset light, therefore they do not have any impetus to acquire spectrum (via auctions or trading) and build a network at present.

An MVNO also noted their operating model could encompass more than just leasing network capacities from MNOs (current MVNO model). In some countries, MVNOs are also allowed to own spectrum. For example, in Malaysia, Altel Communications, an MVNO, attained spectrum in 2.6GHz band and pooled their resources with an MNO, Celcom, to construct an LTE network. Celcom then became the exclusive infrastructure and wholesale provider to Altel, and Altel continued to offer services as an MVNO.

Nonetheless, none of the MVNOs have concrete plans or shown preference towards building their own network.

Factors that will impact the supply and demand for spectrum trading

We asked industry players on their expectations on the volume of transactions if spectrum trading were to be in place in Hong Kong. Many responded that they expect demand of trades to be limited, but it would depend on various market and regulatory factors. We present the factors that industry players feel will impact the supply and demand for spectrum trading below.

- *Supply of spectrum*

Five operators have noted that spectrum supply is currently limited. Therefore, even if there is trading, it is unlikely that operators will want to trade their spectrum.

► *Rules and regulations of spectrum trading regime and auction set-up*

Four operators have remarked that rules and regulations of the spectrum trading regime are a key factor in influencing the volume of transactions expected. Rules on eligibility to trade were highlighted by most operators interviewed. They believed that limiting trading only to MNOs will reduce the expected number of trades; while allowing speculators will likely result in an increase the number of transactions.

One operator remarked that the primary and secondary market for spectrum are inadvertently linked; winners at the auction will in turn be the source of spectrum in the secondary market. If a spectrum trading regime is implemented, rules and regulations of the primary market assignment mechanism (auction) will have to be amended to ensure concerns from implementing a spectrum trading regime are properly addressed. Operators also expect changes to auction rules to potentially affect future participation in spectrum trades.

► *Changes in market dynamics*

One operator responded that if there are changes in market shares resulting in imbalance of spectrum holdings in the market, players with smaller market share (and thus holding excess spectrum to meet their subscriber's demands) might be willing to give up spectrum for a certain price, leading to trade.

However, the operator noted that there is no indication of significant change in market shares in the current market, thus it is unlikely that a lot of transactions will be required to correct any spectrum holding imbalance.

F.4 Comments on alternative mechanisms to spectrum trading

In the current Hong Kong spectrum management regime, there exist two 'alternatives' to spectrum trading, namely, spectrum swaps with no monetary exchange and network leasing capacity from MNOs as an MVNO. We asked operators for their views on each of these topics, and whether they are suitable alternative mechanisms to spectrum trading.

Spectrum swaps

Operators were asked to comment on the spectrum swap mechanism as well as their feedback on the specific swaps between CMHK and SmarTone in the 1800MHz band in 2012; as well as between CMHK and HKT in the 2600MHz band in 2016.

► *Efficacy of spectrum swaps*

Operators have differing opinions with regards to the efficacy of spectrum swaps.

To one operator, spectrum swaps had been able to correct inefficiencies in spectrum use caused by technology evolution and historical assignments. The swap of spectrum within the same band allowed parties to hold contiguous spectrum, increasing spectrum efficiency in these bands.

However, another operator raised concerns about the inflexibility of the mechanism (only spectrum of the same amount and at the same band could be exchanged) and time taken to complete the transaction. As monetary exchanges for spectrum were not permitted, the operator remarked that such mechanisms cannot be used for some of the scenarios described in Section 2.1.

Two operators remarked that regulations involved were not transparent. There were also no public consultations on the transaction prior to approval by the CA. Even though deliberations involved in approving the spectrum swaps were published, some were still unsure if it was a formal mechanism that can be used.

- *Comparison between spectrum swaps and spectrum trading*

Most operators are of the view that spectrum swaps and spectrum trading are inherently different. We compare key variances in the table below:

Figure F.1: Differences between spectrum swap and spectrum trading [Source: Operator interviews, 2017]

	Spectrum swap	Spectrum trading
Financial consideration	Does not involve monetary transfer	Monetary transfer for spectrum is possible
Types of transactions allowed	Symmetrical transactions only (involving spectrum from the same frequency range and of the same amount)	Symmetrical and asymmetrical (i.e. one party acquires spectrum while the other party gives up spectrum) transactions permitted; spectrum of different amounts, and at different bands can be exchanged

Network capacity leasing from MNOs (MVNO mechanism)

MVNO mechanism allows operators who do not own mobile networks to offer mobile services, through leasing of network capacity from MNOs. Industry representative were invited to comment on the existing MVNO mechanism.

- *Efficacy of network capacity leasing from MNOs*

Operators also present different views on the efficacy of MVNO mechanism.

One operator opined that this framework is proven and mature, as MVNOs can rely on MNOs to invest in the network and provide capacity. Another operator commented that this mechanism allows parties to offer services that they were previously unable to offer (e.g. 3G).

However, some commented that the current model is not flexible, and there is an imbalance of power towards MNOs. One MVNO also mentioned that they were excluded from receiving roaming revenues from the current arrangement. An operator has also remarked that MNO can suppress innovations from an MVNO if they deem it to be potential threats.

An operator had remarked that it had experienced some difficulties in serving customers under the MVNO framework as it lacks control in the deployment of base stations. This largely stemmed from the customer base and geography mismatch with its host MNO.

► *Comparison between network capacity leasing and spectrum trading*

Operators mentioned that the MVNO mechanism can coexist with a spectrum trading regime, as spectrum trading will be an added mechanism to acquire spectrum, besides from participating in auctions and M&A of a spectrum holding company. MVNOs under spectrum trading regimes will have more flexibility – they can remain an MVNO and continue to lease capacity from MNOs or opt to acquire spectrum through spectrum trading and build their own network as and when there is a business case for it. We note that MVNOs can also acquire spectrum through participating in auctions from time to time.

An operator's key considerations in the selection of leasing network capacity leasing and acquiring its own spectrum are described in the table below:

Figure F.2: Network capacity leasing and acquiring own spectrum [Source: Operator interviews, 2017]

	Network capacity leasing	Acquiring own spectrum
Financial implications	Only operating expenditure required. Suitable for asset light business strategy	Both operating expenditure and capital expenditure will be incurred through investment in building a network to utilise acquired spectrum. Also results in having network assets in the balance sheet
Control of network	Rely on host for network planning	Full control of network infrastructure and user experience; able to plan coverage and network quality
Scale	Suitable for smaller scale operations	More suitable for larger scale operations
Regulation	MVNO framework is available	Depends on availability of complementary regulations on top of the introduction of spectrum trading to allow new entrant to build a network, e.g. access to infrastructure, fixed network interconnection guidelines

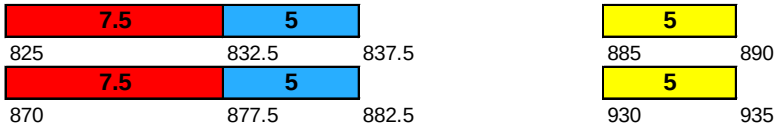
Comments on no-trading

When asked about the impact of not introducing a spectrum trading regime in Hong Kong, feedback from most operators was that it will not impact their current operations. Five operators mentioned that they did not anticipate the introduction of a spectrum trading, and have bided in auctions with the assumption that it will be limited to the constraints of the current regime.

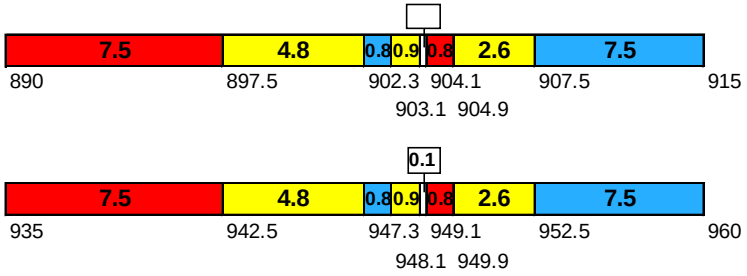
However, one operator remarked that not implementing spectrum trading will cause Hong Kong to lag other development countries in terms of spectrum management policies, as it imposes constraints to spectrum efficiency and deprives users of spectrum from the benefits of spectrum trading.

Annex G Mobile spectrum map of Hong Kong

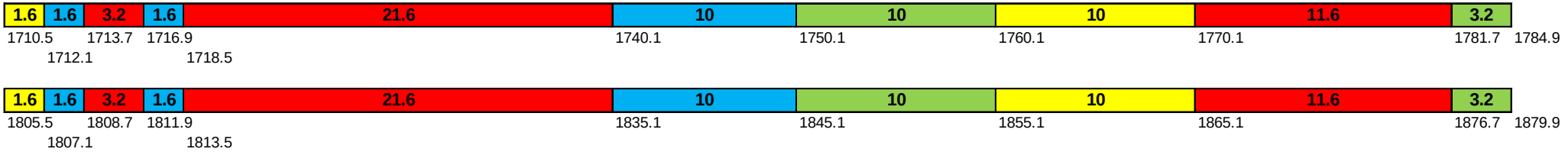
850/900MHz



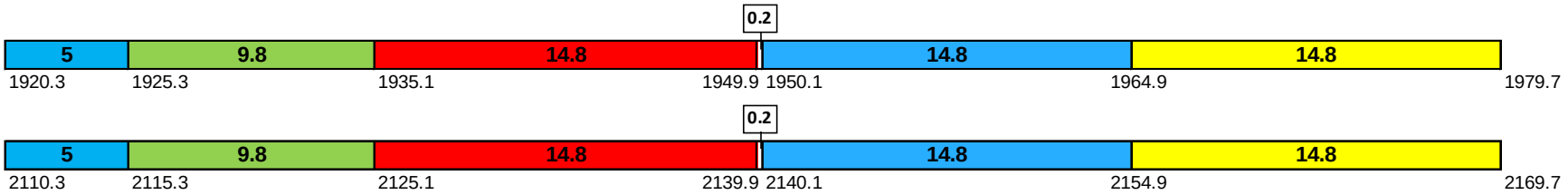
900MHz



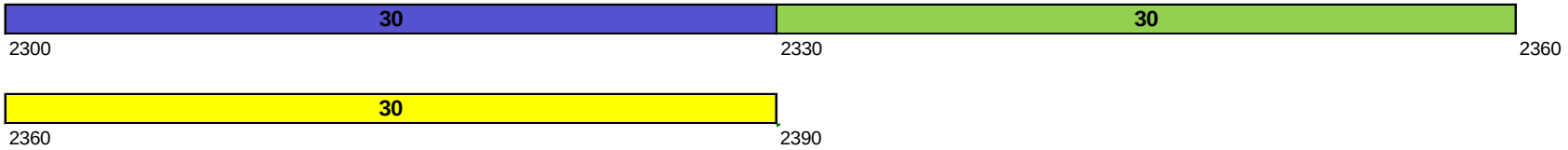
1800MHz



1.9-2.2GHz



2.3GHz[184]



2.5-2.6GHz

Legend:

HKT | Hutchison | CMHK | SmarTone | 21 ViaNet | Genius Brand | Guard band

[184] 2.3 GHz spectrum assigned to 21 ViaNet is deployed for the provision of fixed services