



Spectrum block sizes for the award of the 700MHz band in Colombia

Report for Avantel

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Contents

1	Executive summary.....	4
2	Introduction and background	5
2.1	Current state of competition in the Colombian mobile market	6
2.2	Current proposals for the award of the 700MHz band	7
2.3	Approach taken in this report.....	9
3	Efficient block size for the 700MHz award	10
3.1	Introduction.....	10
3.2	Allocative efficiency of 2x5MHz blocks	10
3.3	Dynamic efficiency of 2x5MHz blocks	11
3.4	Packaging of spectrum in spectrum award processes	11
3.5	Technical efficiency of 2x5MHz blocks	12
3.6	Overall economic efficiency of 2x5MHz blocks	15
4	Benchmarking of 700MHz block sizes	16
4.1	Users of the APT700 band plan in Australia and New Zealand	16
4.2	Users of the North American 700MHz band plan	18
4.3	Comparable bands in other regions.....	19
4.4	Latin American countries that have auctioned the 700MHz band	25
4.5	Summary	29
5	Conclusions.....	33

1 Executive summary

This report has been prepared by Aetha Consulting Limited (Aetha) on behalf of Avantel Colombia. The report outlines the case for using 2x5MHz spectrum blocks in the award process for 700MHz spectrum. The report explains the efficiency gains from using 2x5MHz blocks, and provides extensive benchmarks from 700MHz and 800MHz auctions around the world, which demonstrate that the use of 2x5MHz blocks (and occasionally 2x10MHz) is a standard approach, practised by regulators the world over.

Regulators generally aim to achieve the following from the packaging of spectrum used in auctions:

- ensure that the spectrum is awarded in block sizes that are efficient from a technical perspective
- use a spectrum block size that allows individual operators to aggregate spectrum blocks, both within bands and across bands, to construct packages that they value highly
- use auction mechanisms that allow operators to express their underlying value for different packages
- impose spectrum caps and reservations of spectrum for particular categories of operator if required to protect or enhance the competitiveness of the downstream market for mobile communications.

Auctions that meet the above objectives lead to more efficient outcomes in terms of the allocation of spectrum between different players in the market. A key aspect of meeting such requirements is the use of 2x5MHz blocks. These are the default choice of bandwidth for the licensing of LTE spectrum for the following reasons:

- 2x5MHz provides a sufficiently wide bandwidth to operate efficiently even as a stand-alone carrier
- a 2x5MHz carrier in a sub-1GHz band in combination with 2x15MHz or more in one or more high frequency band has been demonstrated to be a credible, competitive network when competing against networks with a 2x10MHz carrier
- 2x5MHz blocks can be aggregated together to form 5MHz, 10MHz, 15MHz and 20MHz carriers – the four most commonly deployed carrier sizes in LTE.

Many regulators have achieved the above required characteristics for efficient spectrum auctions by using one of the following auction formats:

- Simultaneous Multi-round Ascending Auctions (SMRAs)
- Combinatorial Clock Auctions (CCAs)

The overall impact, is that the use of 2x5MHz blocks with a suitably flexible auction format allows for an overall optimum use of the spectrum – with spectrum allocated according to an operator's willingness to pay (subject to caps and reservations).

This is strongly supported by our benchmarks of past 700/800MHz auctions, which show that 24 out of 30 auctions have used 2x5MHz blocks in their packaging of the bands. In addition, 27 of the 30 auctions have also featured the use of caps and/or reservations so as to ensure that any individual organisation does not acquire an anti-competitive position in respect of its spectrum holdings. In Slovenia for example, a reservation of 2x10MHz was put in place in the 800MHz for new or existing operators with less than 15% market share. This ensured that a weaker player was able to gain crucial low-frequency holdings.

Given the high market concentration in Colombia, and the previous precedent for the use of reservations in the 2013 AWS auction, we note that such a reservation for smaller players in the 700MHz band may prove beneficial in promoting long-term competition in the provision of LTE services.

2 Introduction and background

This report has been prepared by Aetha Consulting Limited (Aetha) on behalf of Avantel Colombia. The report outlines the case for using 2x5MHz spectrum blocks in the award process for 700MHz spectrum. The report explains the efficiency gains from using 2x5MHz blocks, and provides extensive benchmarks from 700MHz and 800MHz auctions around the world, which demonstrate that the use of 2x5MHz blocks (and occasionally 2x10MHz) is a standard approach, practised by regulators the world over.

The Colombian Ministry of Information Technologies and Communications (MINTIC) is currently working on structuring a selection process to allocate spectrum in the 700MHz, 900MHz, 1900MHz, and 2500MHz bands for land mobile services. Under current proposals, it has been suggested that block sizes as large as 2x15MHz could be implemented for the 700MHz band. This approach is both at odds with the established international practise, and runs the risk of leading to an inefficient outcome, whereby some operators are forced to purchase a larger block of spectrum than they would ideally purchase, whereas others are unable to purchase the spectrum they require, despite their willingness to pay for that spectrum.

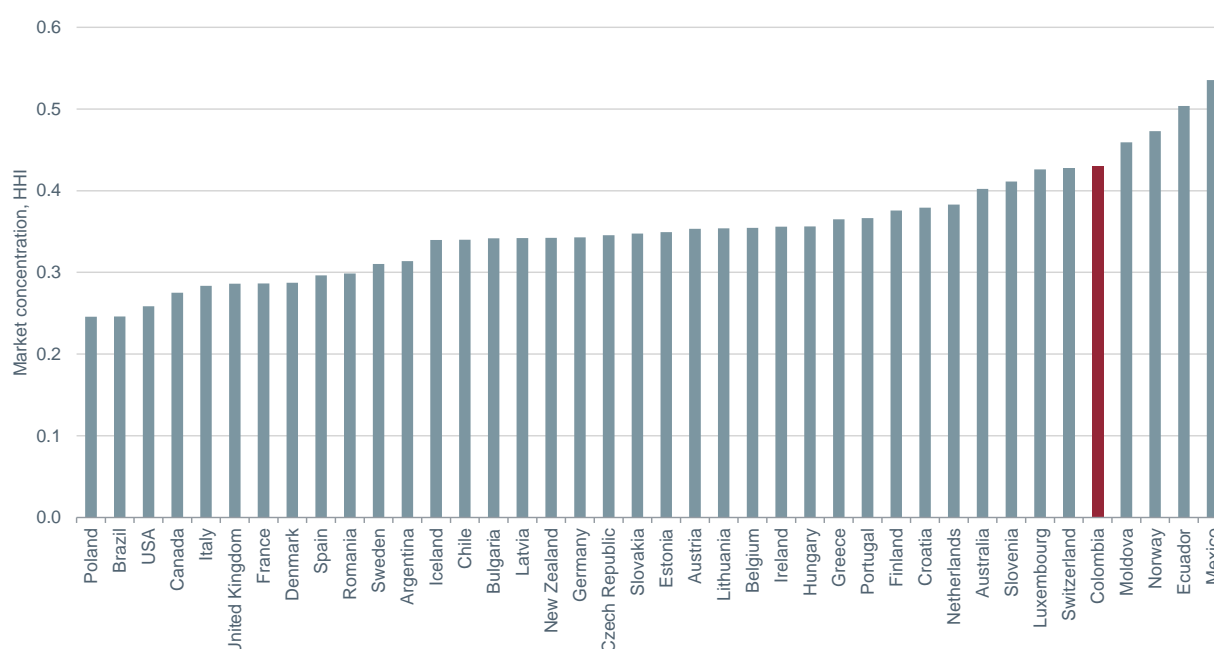
Although the main focus of this report is the block size used for 700MHz, we also provide supporting information regarding the types of auction that allow for efficient outcomes, and we provide some details on caps, reservations and other relevant features of spectrum auction processes used in other markets.

2.1 Current state of competition in the Colombian mobile market

There are currently four mobile network operators in the Colombian market. The market leader Claro currently commands more than 58% of the market, followed by Movistar on 25%, Tigo-UNO on 16% and Avantel on just 0.4%¹. As a result, the two largest players hold more than 83% of subscribers.

Of all countries where the 700MHz or 800MHz band has been auctioned (or assigned), the Colombian market is currently one of the most concentrated. This can be seen in Figure 2-1 below.

Figure 2-1: Market concentration in Colombia vs. countries where the 700/800MHz band has already been auctioned (or assigned)² [Source: Aetha analysis, Q1 2015]



The upcoming auction therefore represents a significant opportunity for the promotion of competition in Colombia, *if* the process is suitably designed and appropriate safeguards put in place. We note also that in the countries where non-competitive assignments in these bands have been made – namely Luxembourg, Moldova and Ecuador – or are planned to be made in the case of Mexico, market concentration is amongst the highest.

Indeed, in its 2014 review of the Colombian mobile market, the OECD stated that:

‘Smaller players and new entrants should be given priority in new spectrum assignments in order to promote market competition. In particular, the upcoming 700MHz auction should ensure that smaller players achieve the right balance between higher and lower frequencies.’³

¹ OECD based on data from MINTIC and CRC.

² Although the spectrum is not yet assigned, we include Mexico in Figure 2-1 as the regulator has already indicated plans to allocate the entire 700MHz band to the creation of a national wholesale network.

³ OECD Publishing, ‘OECD review of telecommunication policy and regulation in Colombia’, 2014.

MINTIC should therefore make it a priority of the auction to ensure that smaller players are able to acquire spectrum in the 700MHz band.

2.2 Current proposals for the award of the 700MHz band

Our understanding of the current distribution of spectrum is summarised in Figure 2-2 below. Avantel has a 2x15MHz of AWS spectrum which it has utilised for the launch of 4G (LTE) services. However its existing sub-1GHz spectrum in the 806MHz band is licensed only for the operation of an iDEN network and is in relatively limited supply (just 9.5MHz in total). Furthermore this spectrum has not been designated by the International Telecommunication Union (ITU) as an International Mobile Telecommunications (IMT) band for the deployment of 3G/4G technologies. We also note that Tigo-UNE does not have sub-1GHz spectrum.

Figure 2-2: Current mobile spectrum holdings (MHz) [Source: MINTIC]

Band	Claro	Movistar	Tigo-UNE	DirecTV	Avantel
Non-IMT-Advanced spectrum					
806MHz					9.5 ⁴
IMT-Advanced spectrum					
850MHz	25	25	-	-	-
AWS (1.7/2.1GHz)	-	30	30	-	30
1900MHz	30 (+5 ⁵)	30	55	-	-
2500MHz	30	-	50	70	-
Total spectrum	85 (+5)	85	135	-	39.5

In a press release of 31 May 2012, MINTIC and the National Spectrum Agency (ANE) announced that Colombia would adopt the FDD channel standard proposed by the Asia-Pacific Telecommunity (APT) for the Digital Dividend band – i.e. 700MHz. In its recent consultation document⁶, the government makes initial proposals for the award of spectrum in this band.

- The 700MHz band spectrum is already mainly cleared and any remaining use for broadcast television should be completed during 2015.
- The 700MHz band could be awarded in two stages:
 - Stage 1 (2016): One block of 30MHz [Alternative 1] or 20MHz [Alternative 2] together with 20MHz of spectrum in the 900MHz band, 5MHz in the 1900MHz band plus 30MHz in the 2500MHz band (which could be offered as one block of 30MHz, two of 15MHz or three of 10MHz).

⁴ This spectrum is licensed solely for the operation of iDEN technologies and is not listed as an IMT-2000 or IMT-Advanced band for the deployment of 3G/4G technologies.

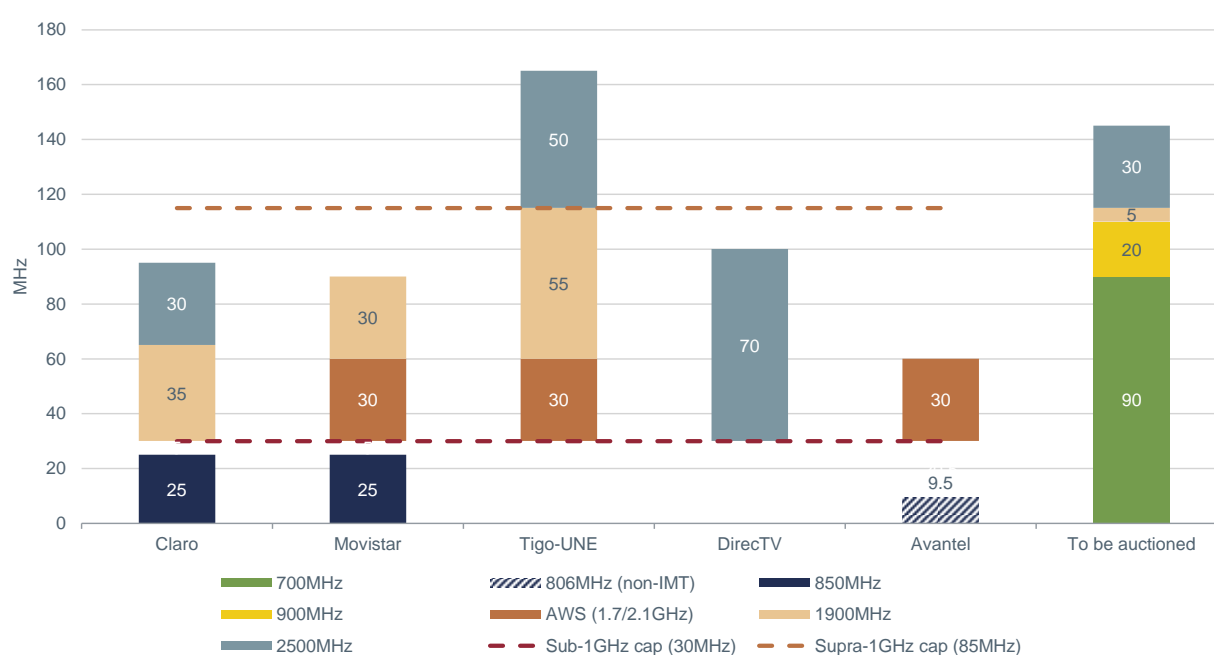
⁵ We understand that Claro was given a temporary assignment of 5MHz of 1900MHz spectrum in October 2011.

⁶ MINTIC, ANE, CRC, vive digital, 'Documento de Consulta Pública: Proceso de selección objetiva para asignación de espectro radioeléctrico en las bandas 700 MHz (Dividendo Digital), 900MHz, 1900MHz y 2500MHz para servicios móviles terrestres', May 2015.

- Stage 2 (2017): 60MHz [Alternative 1] or 70MHz [Alternative 2] with distributions potentially including blocks of 10MHz or 20MHz. 10MHz of the spectrum could be set-aside for use for Public Protection and Disaster Relief (PPDR).
- The consultation document notes that the existing spectrum caps will remain in force (namely a cap of 30MHz on spectrum below 1GHz and a cap of 85MHz on frequencies above 1GHz).
- Coverage obligations would apply – with the coverage requirements being ‘simpler’ than in the AWS auction.

Figure 2-3 below, illustrates in each band, the current holdings as well as spectrum to be awarded.

Figure 2-3: Current mobile spectrum holdings, caps and spectrum to be auctioned
[Source: MINTIC]



As the chart in Figure 2-3 indicates, the 700MHz band represents a significant opportunity for operators to obtain key low-frequency spectrum for LTE services. Both Claro and Movistar are close to the low-frequency cap, and the merged Tigo-UNE currently exceeds the high-frequency cap⁷.

The choice of block sizes is a key determinant in ensuring that all bidders have a fair opportunity to acquire spectrum. 2x5MHz blocks are widely considered to be the minimum suitable for 3G/4G deployment and allow for a more accurate expression of demand given their small size. Arguably 2x10MHz blocks afford marginally higher spectral efficiency in a given band, however carrier aggregation using LTE-Advanced now enables efficient use of a 2x5MHz block in combination with spectrum in other bands to form such a carrier.

⁷ The Superintendence for Industry and Trade has since given the new merged operator a deadline to release the spectrum exceeding the cap.

2.3 Approach taken in this report

The remainder of this report is structured as follows:

- In Section 3, we summarise the key technical and economic benefits of 2x5MHz blocks – e.g. inefficiency of other package constructions.
- In Section 4, we then present the results of our benchmarking of prior auctions to determine the precedent set by
 - users of the APT 700MHz band plan in Australia and New Zealand
 - users of the North American 700MHz band plan
 - comparable bands in other regions – e.g. the European 800MHz band
 - Latin American countries that have auctioned the 700MHz band.
- In Section 5, we then present the key findings of our research, along with our recommendations for the Colombian auction.

3 Efficient block size for the 700MHz award

In this section we discuss the choice of size of spectrum block to be used in the spectrum award, particularly with reference to the size of spectrum blocks in the 700MHz band. In particular we will discuss how a smaller block size of 2x5MHz, with operators being able to aggregate multiple 2x5MHz blocks in the award process is likely to result in a more efficient use of the spectrum.

3.1 Introduction

ANE has proposed that the spectrum award will contain, in a first stage, either a single 30MHz block of digital dividend (700MHz) spectrum or a single 20MHz block of digital dividend spectrum. ANE proposes that in a later, second stage, the award could include 10MHz or 20MHz blocks.

We will argue below that a more efficient process would be to auction 2x5MHz blocks, allowing the operators to aggregate those blocks through the market mechanism of the auction, so that operators are able to construct blocks of different sizes (5MHz, 10MHz, 15MHz or 20 MHz) according to their requirements and their willingness to pay for the spectrum (subject to spectrum caps).

We will consider the efficiency of 2x5MHz blocks of 700MHz spectrum used in isolation, and in addition we will consider the case of 2x5MHz of 700MHz used in carrier aggregation with higher frequencies. Analysis that other regulators have undertaken in preparation for 700MHz and 800MHz award processes suggests that 2x5MHz can be used efficiently in carrier aggregation with other bands.

3.2 Allocative efficiency of 2x5MHz blocks

Because spectrum is a scarce resource, it is important that it can be allocated to the operators according to their technical requirements, and according to their commercial requirements, as indicated by their willingness to pay for the spectrum in an auction. The most efficient allocation of spectrum between different players in the market is therefore achieved by allowing market forces in the auction itself to determine the quantity of spectrum that each player wins.

Regulators therefore generally aim to achieve the following from the packaging of spectrum used in auctions:

- ensure that the spectrum is awarded in block sizes that are efficient from a technical perspective
- use a spectrum block size that allows individual operators to aggregate spectrum blocks, both within bands and across bands, to construct packages that they value highly
- use auction mechanisms that allow operators to express their underlying value for different packages (i.e. different combinations of spectrum blocks – within a band and across bands), as reflected in their willingness to pay for those packages
- impose spectrum caps and reservations of spectrum for particular categories of operator if required to protect or enhance the competitiveness of the downstream market for mobile communications.

Auctions that meet the above objectives lead to more efficient outcomes in terms of the allocation of spectrum between different players in the market. We would also note that another feature of efficient spectrum auctions is that they allow operators to make trade-offs between different quantities of the various bands available in a single process. For this to work, it is necessary that the auction:

- includes all of the spectrum bands available in a single auction process,
- all of the spectrum in each band, in that single process.

A key aspect of meeting the above requirements for an efficient allocation of spectrum is the use of 2x5MHz blocks. A block size of 2x5MHz is the only way to provide operators with the full flexibility to bid for the most efficient spectrum package for their requirements. If large block sizes, such as 15MHz or 20MHz are used in the auction it is not possible for bidders to assemble an optimum combination of spectrum in different bands. Some bidders will have excess spectrum that they do not require, whereas others will be denied access to a particular band, where a more flexible auction might have allowed them to buy 2x5MHz or 2x10MHz of 700MHz spectrum that they require to offer full coverage.

Many regulators have achieved the above required characteristics for efficient spectrum auctions by using one of the following auction formats:

- Simultaneous Multi-round Ascending Auctions (SMRAs)
- Combinatorial Clock Auctions (CCAs)

This is evidenced by the results of our benchmarking which show that 22 out of 30 of the past 700/800MHz auctions reviewed have used such formats. This is discussed in greater detail in Section 4 of this report.

3.3 Dynamic efficiency of 2x5MHz blocks

Because of the rapid evolution in demand for mobile services and the technology used to deliver those services, it is important that the usage of spectrum assignments can be re-configured as requirements change. For example, numerous mobile operators have re-farmed 2G spectrum for use in 3G and 4G, and even 3G spectrum for use in 4G. Furthermore, some operators with excess spectrum, in jurisdictions that allow spectrum trading, have sold spectrum to other players with greater demand for that spectrum. The ability to re-configure the use of spectrum, both internally and in a wider secondary market, enables the efficient use of spectrum through the lifetime of the licence.

The use of a standardised 2x5MHz block size facilitates technological neutrality, the re-farming of spectrum and the secondary market for spectrum. Hence the use of 2x5MHz blocks contributes to an improved dynamic efficiency in the use of spectrum.

3.4 Packaging of spectrum in spectrum award processes

In determining spectrum packages for use in spectrum awards, regulators tend to adopt one of two approaches – the choice of which is related to the choice of award format:

- **Pre-determined spectrum lots and spectrum packages.** The available spectrum is divided into certain specific spectrum lots, or packages of lots across bands, in advance of the award, with the auction being used to determine which organisation acquires each specific lot or package. Specific spectrum lots and spectrum packages may make the auction format simpler, but organisations applying for spectrum do not have the full range of options for acquiring spectrum that could be available if the packaging was determined as part of the auction. This approach therefore requires the regulator to anticipate spectrum requirements of applicants, often leading an inefficient distribution.
- **Auction-determined packaging of spectrum.** Spectrum is divided into a significant number of small units (lots) and the auction process is then used to determine the specific packages of spectrum

acquired by individual organisations. The spectrum lots are often 2x5MHz in the case of FDD bands, so that participants can bid for 5MHz, 10MHz, 15MHz and 20MHz carriers that are envisaged by the technical specifications of LTE. Furthermore, operators can usually bid for flexible combinations of spectrum in different bands, hence optimising their overall spectrum portfolio. Spectrum caps may be set for individual frequency bands / combinations of bands in order to ensure any individual organisation does not acquire an anti-competitive position in respect of its spectrum holdings. Whilst maximising flexibility for applicants, this approach typically requires the use of a more sophisticated auction format such as an SMRA or CCA.

Pre-packaging of bands into larger blocks represents a significant inefficiency because distribution of spectrum is driven by regulatory decision, rather than the needs of the network (technical) or willingness to pay (economic) of the operator.

3.5 Technical efficiency of 2x5MHz blocks

LTE and LTE-Advanced are designed to use spectrum assignments with a bandwidth that is a multiple of 5MHz (e.g. 5MHz, 10MHz, 15MHz, 20MHz). Although LTE can also be used with a smaller allocation of 1.4MHz and 3MHz, it is unusual for such small spectrum assignments to be used, with 5MHz being the minimum that is typically deployed. The vast majority of commercial LTE systems that have been launched use multiples of 5MHz, from 5MHz up to 20MHz (i.e. 5MHz, 10MHz, 15MHz, 20MHz).

3.5.1 Minimum efficient bandwidth for LTE channels

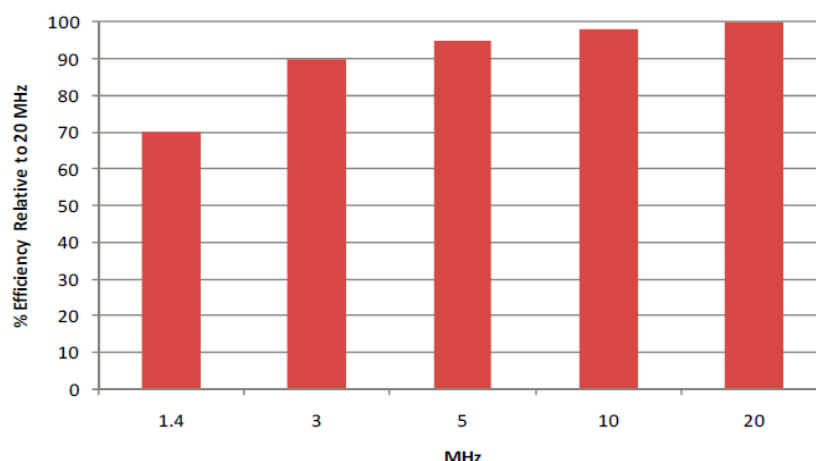
In an LTE network, as in any communications link, radio resources are used more efficiently in a wide bandwidth carrier than in a narrow bandwidth carrier. This is because the statistical multiplexing of traffic from multiple users is more efficient in a higher capacity link which aggregates demand from a larger number of users, leading to a less 'peaky' traffic pattern, allowing for a greater loading of the link for a given grade of service. This type of statistical effect is very familiar from voice communications where it is known as 'trunking efficiency' - characterised in the non-linear relationship between the capacity of a link (measured in Erlangs) and the number of voice channels available in the link. Although the statistical multiplexing of data traffic is different to voice, there is a broadly similar type of effect, leading to wider channels being used more efficiently than narrow channels, for an equivalent grade of service.

Wide bandwidth radio channels in LTE (such as 20MHz) are therefore bound to be more efficient than narrow channels (such as 1.4MHz), where efficiency is measured as the channel throughput in Mbit/s per MHz of spectrum for a certain grade of service. It is therefore important that LTE channels are not too narrow, such that the spectrum is used inefficiently as a result of inefficient statistical multiplexing.

This efficiency of different channel widths for LTE, given the characteristics of end user traffic, has been estimated by various operators. For example, a paper by Rysavy Research⁸ presents the expected relative efficiency of each of the possible LTE channel widths compared to the largest channel of 20MHz, based on analysis from members of 4G Americas. Figure 3-1 shows the results presented by Rysavy Research.

⁸ Rysavy Research, 4G Americas, 'Beyond LTE: Enabling the Mobile Broadband Explosion', August 2014.

Figure 3-1:
Percentage efficiency of
carrier relative to 20MHz
 [Source: Rysavy
 Research]



The chart shows that at 1.4MHz channel width, the efficiency of use of the spectrum is only 70% of the efficiency of a 20MHz channel and at 3MHz channel width the efficiency is 90% of the efficiency of a 20MHz channel. When a 5MHz channel is used, the efficiency is approximately 93% of the efficiency of a 20MHz channel. These results suggest that to use a 1.4MHz channel is inefficient, whereas a 5MHz channel suffers from only a small inefficiency compared to a 20MHz channel. This result suggests that there is no risk of poor efficiency from using 2x5MHz blocks for LTE, even if an operator were to purchase just a single block.

3.5.2 2x5MHz blocks in combination with other frequency bands

The results discussed above relate to the efficiency of an LTE channel of a single frequency band, used in isolation. However, it is likely that an operator using 5MHz of spectrum for LTE in the 700MHz band will be combining that spectrum with spectrum in a higher frequency band (such as AWS spectrum) using carrier aggregation.

The case of an LTE network using a 5MHz carrier in 800MHz, in carrier aggregation with higher frequency spectrum in the 1800MHz band was studied by the UK regulator Ofcom as part of its preparation for the UK 800MHz and 2.6GHz auction in 2013. Ofcom undertook technical studies to ascertain whether a 2x5MHz channel, in carrier aggregation with higher spectrum bands, would enable an operator to offer a credible, competitive, LTE network.

In the context of considering spectrum options for the fourth UK player (Three⁹), Ofcom undertook detailed technical planning, RF coverage and end user bandwidth simulation. The four possible spectrum portfolios that Ofcom considered as possibilities for Three are shown in Figure 2-2.

⁹ Also known as H3G or the name of its parent group, Hutchison Whampoa.

Figure 3-2: Alternative portfolios that Ofcom considered could enable Three to be credible
[Source: Ofcom¹⁰]

	Additional spectrum			Existing spectrum	Summary of assessment
	800 MHz	1800 MHz	2.6 GHz	2.1 GHz	
	2 x 10 MHz	-	-	2 x 15 MHz	Low level of confidence that H3G would be credible
	-	2 x 15 MHz	-	2 x 15 MHz	
	-	2 x 15 MHz	2 x 10 MHz	2 x 15 MHz	
Portfolio 1	2 x 15 MHz	-	-	2 x 15 MHz	Likely to be sufficient spectrum for credibility
Portfolio 2	2 x 10 MHz	-	2 x 10 MHz	2 x 15 MHz	
Portfolio 3	2 x 5 MHz	2 x 15 MHz	-	2 x 15 MHz	
Portfolio 4	-	2 x 15 MHz	2 x 20 MHz	2 x 15 MHz	

Ofcom's conclusion, after detailed studies and consultation, was that Three would be a credible (i.e. competitive) operator with just 2x5MHz of 800MHz spectrum if that was combined with a portfolio of spectrum that included 2x15MHz of 1800MHz spectrum and 2x15MHz of 2.1GHz spectrum. Ofcom's analysis took into account the site grid of Three and the relative performance of the spectrum bands, including relative building penetration losses.

As a result of its analysis, Ofcom designed the award process so that the minimum amount of 800MHz spectrum that an operator could win was 2x5MHz – providing the operators with maximum flexibility to purchase different quantities of 800MHz spectrum.

We note that in the Americas, the 700MHz and AWS bands are broad equivalents to the 800MHz and 1800MHz bands used in Europe, with both sets of complementary bands forming a common feature of LTE deployments in their respective regions. This is reflected in the strong device ecosystems which support the carrier aggregation of these bands. In the US for example, Verizon, AT&T and T-Mobile have all indicated that they will be implementing 700MHz/AWS carrier aggregation in 2015.¹¹

3.5.3 Standards built around multiples of 5MHz

The technical standards for LTE have been designed around the concept of multiples of 2x5MHz for FDD, with 3GPP release 8 standards allowing carriers up to 20MHz and release 10 allowing aggregation of different carriers in multiples of 5MHz up to a maximum aggregated bandwidth of 100MHz.

5MHz is therefore the intrinsic unit of bandwidth for LTE carriers, making it the essential 'building block' from which the other carrier bandwidths and carrier aggregations are constructed.

In Colombia, the 850MHz band is currently used for GSM/UMTS services by Claro and Movistar. It is possible that this may cause interference to LTE networks using the 900MHz spectrum that is to be included in the upcoming auction. An example of this occurred in New Zealand, where Vodafone initiated legal proceedings against Telecom New Zealand over interference to its 900MHz network caused by Telecom's 850MHz network. It is true that measures can be taken to prevent such interference from

¹⁰ Ofcom, 'Assessment of future mobile competition and award of 800MHz and 2.6GHz', Annex 2, July 2012.

¹¹ Root Metrics, 'Will carriers' bid network plans for 2015 make a big difference in performance?', 14 January 2015

occurring, but it should be noted that such measures come at additional cost. In Australia for example, the bottom 2x10MHz of the 900MHz is not used and an additional 1.6MHz¹² guard band separates the 850MHz band below. Regarding the operation of Telstra's 850MHz network and Vodafone's 900MHz network, we also note that Telstra has managed interference through the installation of additional filters to its base stations.¹³ Spatial separation of sites could also be employed, but would require a greater degree of coordination between operators.

The use of a 2x5MHz block size in the 900MHz band would enable greater flexibility in the band plan to mitigate interference issues.

In summary, multiples of 2x5MHz are the default choice of bandwidth for the licensing of LTE spectrum for the following reasons:

- 2x5MHz provides a sufficiently wide bandwidth carrier to operate efficiently even as a stand-alone carrier
- a 2x5MHz carrier in a sub-1GHz band in combination with 2x15MHz or more in one or more high frequency band has been demonstrated to be a credible, competitive network when competing against networks with a 2x10MHz carrier – as evidenced by the detailed assessment by Ofcom in advance of the UK 800MHz/2.6GHz auction
- 2x5MHz blocks can be aggregated together to form 5MHz, 10MHz, 15MHz and 20MHz carriers – the four most commonly deployed carrier sizes in LTE.

Although larger carrier sizes, such as 20MHz also ensure the same technical efficiency as 2x5MHz, it is less efficient to force operators to use larger carriers as we will demonstrate below.

3.6 Overall economic efficiency of 2x5MHz blocks

In the sections above we have discussed how the use of 2x5MHz blocks in an auction allows for:

- a technically efficient use of spectrum – even if the 2x5MHz block alone is used for LTE
- a credible, competitive, network if a single 2x5MHz block is combined with wider bandwidth carriers at a higher frequency
- the ability for operators to create optimised combinations of spectrum bands, with bandwidths of between 5MHz and 20MHz in each spectrum band.

The overall impact, is that the use of 2x5MHz blocks with a suitably flexible auction format allows for an overall optimum use of the spectrum – with spectrum allocated according to an operator's willingness to pay (subject to caps and reservations to safeguard competition).

¹² Telstra, 'The 900MHz band – exploring new opportunities', 24 June 2011.

¹³ ACMA, 'The 803–960MHz band – exploring options for future change', December 2012.

4 Benchmarking of 700MHz block sizes

The 700MHz band has already been auctioned in a number of countries throughout ITU Region 2 (Americas) and Region 3 (Asia-Pacific), and now serves as the key low-frequency coverage band for the delivery of LTE services. Similarly, the 800MHz band serves the same purpose throughout ITU Region 1 (Europe, Middle East and Africa).

We note that from our benchmarking of past 700MHz and 800MHz auctions, the vast majority of auctions have featured a complete or partial packaging of the bands into 2x5MHz blocks. As such there is a strong precedent for such an arrangement to be adopted in Colombia.

As discussed in Section 3, the pre-packaging of bands into larger blocks represents a significant inefficiency because distribution of spectrum is driven by regulatory decision rather than by the requirements of the operators. With smaller blocks there is more flexibility for bidders, whilst competitive safeguards such as caps and/or reservations may still be set to ensure any individual organisation does not acquire an anti-competitive position in respect of its spectrum holdings.

In this section, we review the spectrum packaging used in each of the relevant completed auctions, noting in addition where caps and/or reservations were also used by regulators. We include details of the amount of spectrum awarded in each band. We also note for each auction, whether the blocks were specific – i.e. relating to a specific frequency position within the band – or generic – i.e. relating to an abstract bandwidth within the band, to be determined by a secondary frequency assignment stage.

4.1 Users of the APT700 band plan in Australia and New Zealand

Prior to its widespread adoption in Latin America, the APT700 band plan was pioneered in the Asia-Pacific region. Notably, two key auctions took place in 2013 as summarised in the table below.

Figure 4-1: 700MHz auctions (APT band plan) in Australia and New Zealand [Source: Aetha]

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/Generic	Caps	Reservations
New Zealand Package clock auction (Sep 13)	700MHz	2x45	9 lots of 2x5MHz	Generic with assignment round	2x15MHz (unless supply exceeds demand)	n/a
Australia CCA (May 13)	700MHz 2.5GHz	2x45 2x70	9 lots of 2x5MHz (700MHz) 14 lots of 2x5MHz (2.5GHz)	Generic with assignment round	2x25 for 700MHz 2x40MHz for 2.5GHz	n/a

We now explore the rules and outcomes of each of these auctions in more detail.

4.1.1 New Zealand

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/Generic	Caps	Reservations
Package clock auction (Sep 13)	700MHz	2x45	9 lots of 2x5MHz	Generic with assignment round	2x15MHz (unless supply exceeds demand)	n/a

Spectrum was offered as nine generic lots of 2x5MHz. Notably in New Zealand, the cap of 2x15MHz (out of the 2x45MHz available) guaranteed each of the three bidders up to three blocks in the band (effectively acting as a reservation for each operator). With the third operator, 2degrees only bidding for two blocks, this left one unsold block – acquired by Telecom New Zealand in a subsequent phase of the award process.

In this example, the cap in the first phase of the auction ensured that the smaller operator could not be squeezed out of the band, whilst the block sizes ensured that the operators could choose to express their lower demand if they wished. A 2x20MHz cap for example, could have left 2degrees with just 2x5MHz of spectrum.

4.1.2 Australia

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/Generic	Caps	Reservations
CCA (May 13)	700MHz 2.5GHz	2x45 2x70	9 lots of 2x5MHz (700MHz) 14 lots of 2x5MHz (2.5GHz)	Generic with assignment round	2x25 for 700MHz 2x40MHz for 2.5GHz	n/a

Spectrum in the 700MHz band was offered as nine generic lots of 2x5MHz, licensed on a national basis with a generous cap of 2x25MHz. Similarly the 2.5GHz band was packaged as 14 generic lots of 2x5MHz but with each lot available as one of 11 regional licences, subject to a cap of 2x40MHz within each region.

In this auction, the reserve price for 700MHz was set at an extremely high level of USD1.25/MHz/pop. As a consequence the auction resulted in Telstra gaining 2x20MHz, Optus gaining 2x10MHz and the third operator, Vodafone Hutchison Australia (VHA) not acquiring any 700MHz spectrum. As such 2x15MHz was unsold and is likely to remain unused for a considerable period, to the detriment of both consumers and the Australian economy.

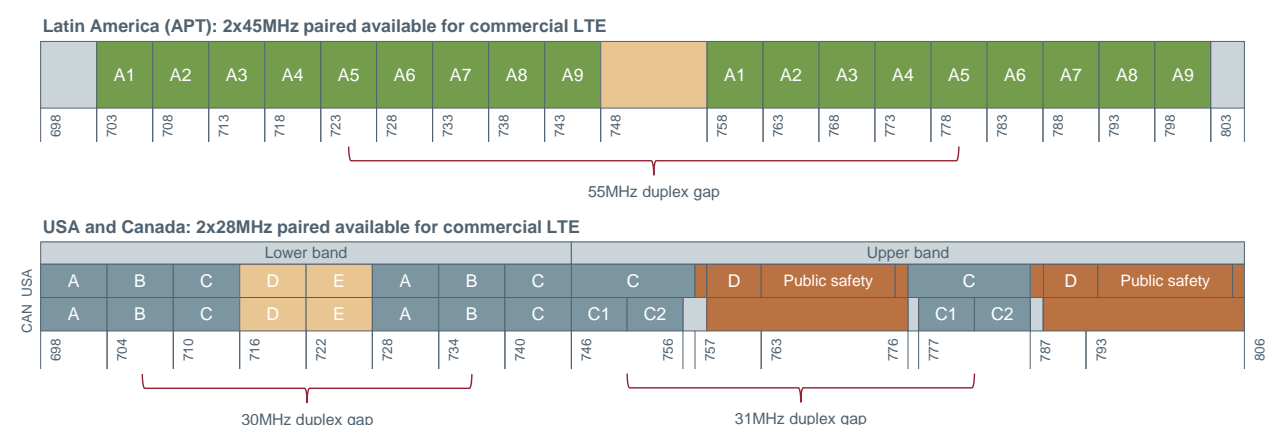
The outcome of this auction appears to have been extremely damaging to competition in the market, with VHA losing significant market share to Telstra in the period since.¹⁴

¹⁴ ACMA, 'Communications report 2013-14', Nov 2014.

4.2 Users of the North American 700MHz band plan

Due to the use of certain frequencies for public safety in the US, the North American band plan for the 700MHz band is more fragmented than the APT700 band plan prevalent in Latin America, offering 2x28MHz for commercial LTE across two sub-bands, as opposed to 2x45MHz. A comparison of the band plans is represented in the diagram below.

Figure 4-2: Comparison of band plans in use in Latin America, USA and Canada [Source: Aetha]



As a result of the different band plans, the choice of block sizes in the USA and Canada is not applicable to a Colombian context. It can be noted however that the packaging comprises mainly blocks of 2x5MHz or 2x6MHz (6MHz channels were used to maintain compatibility with the previous use of the band for broadcasting).

Figure 4-3: 700MHz auctions (North American band plan) [Source: Aetha]

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/Generic	Caps	Reservations
Canada CCA (Feb 14)	700MHz	2x28 1x12	3 lots of 2x6MHz 2 lots of 1x6MHz 2 lots of 2x5MHz (all lots licensed in 14 service areas)	Generic with assignment round	Two of lots A, B, C, C1, C2 One of lots B, C, C1, C2 for operators with greater than 10% national market share (or 20% in the region of the licence)	n/a ¹⁵
USA SMRA (Mar 08)	700MHz	2x36 1x12	3 lots of 2x6MHz 2 lots of 1x6MHz 1 lot of 2x11MHz 2 lots of 2x1MHz 1 lot of 2x5MHz	Generic with assignment round	n/a	n/a

¹⁵ Although no reservation was used in the 700MHz auction, we note that in the more recent AWS-3 auction held on 3 March 2015, 2x30MHz (60% of the auctioned spectrum) was reserved for 'new entrants' (as defined by a population coverage threshold).

4.2.1 Canada

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/Generic	Caps	Reservations
CCA (Feb 14)	700MHz	2x28 1x12	3 lots of 2x6MHz 2 lots of 1x6MHz 2 lots of 2x5MHz (all lots licensed in 14 service areas)	Generic with assignment round	Two of lots A, B, C, C1, C2 One of lots B, C, C1, C2 for operators with greater than 10% national market share (or 20% in the region of the licence)	n/a ¹⁶

Spectrum was offered in lots of 5/6MHz including two lots of unpaired spectrum. Notably in Canada, the following caps were imposed:

- maximum of two of the paired blocks A, B, C, C1 or C2 (see Figure 4-2)
- maximum of one of the paired blocks B, C, C1 or C2 applicable to all licensees which are ‘large wireless service providers’, where these are defined as:
 - ‘...companies with 10% or more of the national wireless subscriber market share, or 20% or more of the wireless subscriber market share in the province of the relevant licence area.’¹⁷

As such, only one of the three largest operators (Rogers, TCC and Bell Group) could acquire more than one paired block. This ensured that a fourth operator could not be squeezed out, whilst maintaining competition for a second paired block.

In the majority of regions, the market leader Rogers was able to gain contiguous blocks A and B. This will allow it to deploy a full 2x10MHz LTE carrier, which may also be carrier aggregated with other bands.¹⁸

4.3 Comparable bands in other regions

Throughout ITU Region 1 (Europe, Middle East and Africa), the 800MHz band serves as the key low-frequency band for LTE. As such, countries where this band has been auctioned can be used to provide a useful secondary set of benchmarks for comparison with the 700MHz band to be auctioned in Colombia. In particular we note that the 800MHz band has now been awarded in almost all European countries. The following table summarises these awards.

¹⁶ Although no reservation was used in the 700MHz auction, we note that in the more recent AWS-3 auction held on 3 March 2015, 2x30MHz (60% of the auctioned spectrum) was reserved for ‘new entrants’ (as defined by a population coverage threshold).

¹⁷ Industry Canada, ‘Licensing framework for mobile broadband services (MBS) – 700MHz band’, March 2013.

¹⁸ Rysavy Research, ‘Canadian 700MHz auction: Analysis of Results’, 2 April 2014.

Figure 4-4: 800MHz auctions [Source: Aetha]

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/ Generic	Caps	Reservations
Greece SMRA (Oct 14)	800MHz 2.5GHz (FDD) 2.5GHz (TDD)	2x30 2x70 1x30	6 lots of 2x5MHz (all other bands in 5MHz blocks)	Generic with assignment round	800MHz (2x15) 2.5GHz FDD&TDD (70MHz)	800MHz (2x5 to each operator)
Slovenia CCA (Apr 14)	800MHz 900MHz 1800MHz 2.1GHz (FDD) 2.1GHz (TDD) 2.5GHz (FDD) 2.5GHz (TDD)	2x30 2x35 2x75 2x5 1x20 2x70 1x50	6 lots of 2x5MHz (5MHz blocks for all other bands)	Generic with assignment round	Sub-1GHz (2x30) 900MHz (2x15) 1800MHz (2x30) Total paired (2x105)	800MHz (2x10) for new entrants or existing operators with less than 15% market share
Slovak Republic CCA (Dec 13)	800MHz 1800MHz 2.5GHz (FDD) 2.5GHz (TDD)	2x30 2x20.4 2x70 1x50	6 lots of 2x5MHz (5MHz blocks for 2.5GHz band also, but 1800MHz band split into blocks of 5MHz, 1MHz, 1.2MHz, 2.2MHz, 0.4MHz, 0.6MHz)	Generic with assignment round	800MHz (2x10) 1800MHz (2x15.2)	n/a
Croatia Assignment (Oct 12) First-price sealed bid (Nov 13)	800MHz	2x30	2 lots of 2x10MHz assigned then 2 lots of 2x5MHz auctioned	Specific	2x10MHz in original assignment	n/a
Belgium SMRA (Nov 13)	800MHz	2x30	3 lots of 2x10MHz	Specific	2x10MHz	n/a
Austria CCA (Oct 13)	800MHz 900MHz 1800MHz	2x30 2x35 2x75	6 lots of 2x5MHz (5Hz blocks all other bands)	Generic with assignment round	800MHzx (2x20) 900MHz (2x30) Sub-1GHz (2x35) Total paired (2x70)	800MHz (2x10) for new entrant in a 'pre-auction'
Lithuania SMRA (Oct 13)	800MHz	2x30	4 lots of 2x5MHz 1 lot of 2x10MHz (subject to coverage obligation)	Generic with assignment round	2x10MHz	n/a
Latvia SMRA (Oct 13)	800MHz	2x30	3 lots of 2x10MHz	Specific	n/a	n/a
Finland SMRA (Oct 13)	800MHz	2x30	6 lots of 2x5MHz	Specific (but with ability to switch between blocks)	2x15MHz	n/a
Estonia Beauty contest (Jun 13) Multi-round auction (Aug 13) Multi-round auction (Jan14)	800MHz	2x30	3 lots of 2x10MHz awarded in separate processes	Specific	Winners of previous lots could not bid again	n/a

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/ Generic	Caps	Reservations
Iceland SMRA (Feb 13)	800MHz 1800MHz	2x30 2x25	4 lots of 2x5MHz 1 lot of 2x10MHz (Cat A - subject to coverage obligation and available for longer 25-year duration)	Specific	800MHz (2x20) 1800MHz (2x15 if holder of 900/2100MHz, else 2x20) 800MHz&1800MHz (for holder of 900/2100, unless awarded Cat A in which case 2x25)	n/a
UK CCA (Feb 13)	800MHz 2.5GHz (FDD) 2.5GHz (TDD)	2x30 2x70 2x50	4 lots of 2x5MHz 1 lot of 2x10MHz (subject to coverage obligation) (all other bands in 5MHz blocks)	800MHz 2x10MHz block specific, all others generic	Sub -1GHz (2x27.5MHz) Total cap of 210MHz (excluding 2.5GHz TDD holdings) Total cap of 215MHz (including 2.5GHz TDD holdings)	Floors used (see Section 4.5.3)
Netherlands CCA (Dec 12)	800MHz 900MHz 1800MHz 2.1GHz (FDD) 2.1GHz (TDD) 2.5GHz (TDD)	2x30 2x35 2x70 2x10 1x14.6 1x55	6 lots of 2x5MHz (all other bands in 5MHz blocks)	Generic with assignment round	800MHz/900MHz reserved spectrum (2x10) 190 activity points for incumbents, 220 for new entrants	800MHz (2x10) 900MHz (2x5)
Ireland CCA (Nov 12)	800MHz 900MHz 1800MHz	2x30 2x35 2x75	6 lots of 2x5MHz (all other bands in 5MHz blocks)	Generic with assignment round	Sub-1GHz (2x20) 900MHz (2x10) for short-term licence Total cap of 2x50MHz FDD across the 800MHz, 900MHz and 1800MHz bands	n/a
Romania Package clock auction (Sep 12)	800MHz 900MHz 1800MHz 2.5GHz (FDD) 2.5GHz (TDD)	2x30 2x35 2x75 2x70 1x45	6 lots of 2x5MHz (all other long-term licences in 5MHz blocks except for 2.5GHz TDD in 3 blocks of 15MHz)	Generic with assignment round	800MHz (2x10) 900MHz (2x10) Sub-1GHz (2x20)	n/a
Denmark CCA (Jun 12)	800MHz	2x30	4 lots of 2x5MHz 1 lot of 2x10MHz (subject to usage restrictions)	800MHz 2x10MHz block specific, all others generic	800MHz (2x20)	n/a
Switzerland CCA (Feb 12)	800MHz 900MHz 1800MHz 2.1GHz (FDD) 2.1GHz (TDD) 2.5GHz (FDD) 2.5GHz (TDD)	2x30 2x35 2x75 2x60 1x20 2x70 45	6 lots of 2x5MHz (all other bands in 5MHz blocks except for one 2x10MHz block of 1800MHz)	Generic with assignment round	900MHz (2x20) 1800MHz (2x35) 2.1GHz (2x30) Sub-1GHz (2x25) Total paired (2x135)	n/a

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/Generic	Caps	Reservations
France ¹⁹ Combinatoria I sealed-bid (Dec 11)	800MHz	2x30	2 lots of 2x5MHz 2 lots of 2x10MHz	Specific	800MHz (2x15)	n/a
Portugal SMRA (Dec 11)	450MHz 800MHz 900MHz 1800MHz 2.1GHz (TDD) 2.5GHz (FDD) 2.5GHz (TDD)	2x1.25 2x30 2x10 2x57 1x10 2x70 1x50	1 lot of 2x1.25MHz 6 lots of 2x5MHz 2 lots of 2x5MHz 9 2x5MHz, 3 2x4MHz 2 lots of 5MHz 14 lots of 2x5MHz 2 lots of 25MHz	Generic with assignment round	800MHz (2x10) 900MHz (2x5) for bidders with existing holdings in the band 1800MHz (2x20) including existing holdings 2.5GHz (2x20)	n/a
Italy SMRA (Sep 11)	800MHz 1800MHz 2.1GHz (TDD) 2.5GHz (FDD) 2.5GHz (TDD)	2x30 2x15 1x15 2x60 1x30	6 lots of 2x5MHz 3 lots of 2x5MHz 1 lot of 15MHz 12 lots of 2x5MHz 2 lots of 15MHz	One 800MHz, one 2.5GHz FDD, and all TDD blocks specific	Sub-1GHz (2x25) 1800MHz (2x25) 2.5GHz (55MHz)	n/a
Spain SMRA (Jul 11)	800MHz 900MHz 2.5GHz (FDD) 2.5GHz (TDD)	2x30 2x10 2x70 ²⁰ 1x50	6 lots of 2x5MHz (all other bands in 5MHz blocks except for some 10MHz 2.5GHz blocks)	All generic except for lowest 800MHz block and TDD blocks	800MHz (2x10) 2.5GHz (2x20) Sub-1GHz (2x20) including existing holdings Supra-1GHz (115MHz)	n/a
Sweden SMRA (Mar 11)	800MHz	2x30	6 lots of 2x5MHz	Generic with assignment round	800MHz (2x10)	n/a
Germany SMRA (May 10)	800MHz 1800MHz 2.1GHz (FDD) 2.1GHz (TDD) 2.5GHz (FDD) 2.5GHz (FDD)	2x30 2x25 2x20 1x19 2x70 1x50	6 lots of 2x5MHz (all other bands in 5MHz blocks)	All generic except for: lowest 800MHz block, upper 1800MHz block, 4 2.1GHz blocks	Sub-1GHz (2x22.5 ²¹)	n/a

¹⁹ We note that the French regulator has recently announced that it intends to auction the 700MHz band in blocks of 2x5MHz and using an SMRA auction format in Q4 2015. Bidders will be subject to a cap of 2x15MHz within the band, as well as a sub-1GHz cap of 2x30MHz.

ARCEP Press release, 'L'ARCEP soumet pour avis à la commission consultative des communications électroniques les modalités d'attribution et d'usage des fréquences 700 MHz', 19 June 2015.

²⁰ Includes some licences split regionally.

²¹ The Bundesnetzagentur officially defined a sub-1GHz spectrum cap of 2x20MHz. However, this cap was relaxed for Deutsche Telekom and Vodafone such that the operators could acquire 2x10MHz in the 800MHz band (in addition to the 2x12.4MHz held in the 900MHz band). Hence this was effectively a 2x22.5GHz cap.

In addition to the above auctions, we note that there have been two further assignments of 800MHz spectrum in Moldova and Luxembourg. In Moldova 2x10MHz was assigned to Orange Moldova and Moldcell (leaving 2x10MHz unallocated), whilst in Luxembourg 2x10MHz was assigned to each of the three incumbents.

In the following subsections, we highlight particular cases where the actions of the regulator served to ensure a competitive outcome following the auction.

4.3.1 Slovenia

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/ Generic	Caps	Reservations
CCA (Apr 14)	800MHz	2x30	6 lots of 2x5MHz (5MHz blocks for all other bands)	Generic with assignment round	Sub-1GHz (2x30) 900MHz (2x15) 1800MHz (2x30) Total paired (2x105)	800MHz (2x10) for new entrants or existing operators with less than 15% market share
	900MHz	2x35				
	1800MHz	2x75				
	2.1GHz (FDD)	2x5				
	2.1GHz (TDD)	1x20				
	2.5GHz (FDD)	2x70				
	2.5GHz (TDD)	1x50				

In the Slovenian multi-band auction, all bands were available in 5MHz lots. Notably, a reservation of up to 2x10MHz (in two blocks of 2x5MHz) was made available in the 800MHz band for new entrants or existing operators with less than 15% market share. The reservation was designed such that eligible bidders could indicate their demand for the reserved blocks in their initial bids. If there was insufficient demand, one or more of these blocks could then be made available for all bidders.²²

Notably, this ensured that Tušmobil, the country's third largest operator was able to gain both blocks of reserved spectrum. This was a successful outcome, in ensuring the existence of a competitive third player in the market. This was of particular importance to the regulator, given the high concentration in the market – comparable to that in Colombia (as can be seen in Figure 2-1). The two largest operators, Mobitel and Si.mobil hold approximately 85% of the market, with the third and fourth operators holding ~12% and ~3% respectively. Given a population of just two million people, Slovenia is the smallest European market with four players. It was therefore unclear if the market could sustain four competitive players. The regulator therefore decided that a reasonable objective for the auction would be to ensure that *at least* three operators gained sufficient spectrum to enable them to compete sustainably in the market. As a result, the auction also did not preclude outcomes in which four, or even more, operators win spectrum.

²² AKOS, 'Public tender with a public auction for assigning radio frequencies for the provision of public communication services in the 800MHz, 900MHz, 1800MHz, 1800MHz, 2100MHz and 2600MHz frequency bands', December 2013.

4.3.2 UK

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/ Generic	Caps	Reservations
CCA (Feb 13)	800MHz 2.5GHz (FDD) 2.5GHz (TDD)	2x30 2x70 2x50	4 lots of 2x5MHz 1 lot of 2x10MHz (subject to coverage obligation) (all other bands in 5MHz blocks)	800MHz 2x10MHz block specific, all others generic	Sub -1GHz (2x27.5MHz) Total cap of 210MHz (excluding 2.5GHz TDD holdings) Total cap of 215MHz (including 2.5GHz TDD holdings)	Floors used (see Section 4.5.3)

In the 2013 UK auction, which covered the 800MHz and 2.6GHz bands, all lots were available in 5MHz blocks, except for one 2x10MHz block in the 800MHz band. This was created for the purpose of attaching a coverage obligation, where it was deemed that fulfilling the obligation with a 2x5MHz block would be unduly harsh.

Most notably, Ofcom introduced a new concept to ensure that at least four mobile operators would gain access to a sufficient amount of spectrum after the auction. Based on a detailed assessment of the needs of mobile operators to offer competitive services in the long term, Ofcom defined a set of so-called ‘spectrum portfolios’ (as discussed briefly in Section 3.5.2) – which effectively acted as a spectrum floor.

Based on its analysis, Ofcom concluded that the following set of spectrum portfolios would offer a sufficient amount of spectrum to either Three (the fourth operator) or a new entrant.

Figure 4-5: UK spectrum floors [Source: Ofcom, July 2012²³]

Floor	800MHz spectrum	1800MHz spectrum	2.6GHz spectrum
1	2x15MHz	-	-
2	2x10MHz	-	2x10MHz
3	2x5MHz	2x15MHz	-
4	-	2x15MHz	2x20MHz

All operators deemed as not holding sufficient spectrum prior to the auction to be considered a credible (wholesale) operator (i.e. Three and entrant bidders), were given the opportunity to take part in an ‘opt-in’ round prior to the auction. Within this opt-in round, the operators could decide to bid on a list of potential spectrum portfolios based on their existing holdings and the level of eligibility points as expressed in the application bid. The figure below summarises the different opt-in lists which were available to bidders.

²³ Ofcom, ‘Assessment of future mobile competition and award of 800 MHz and 2.6 GHz’, July 2012.

Figure 4-6: Opt-in round lists [Source: Ofcom]

List	Criteria	800MHz spectrum	2.6GHz spectrum	Price
A	No 1800MHz holdings	2x15MHz 2x10MHz	- 2x10MHz	GBP675 million GBP480 million
B	No 1800MHz holdings	2x15MHz 2x10MHz 2x15MHz* 2x10MHz*	- 2x10MHz - 2x10MHz	GBP675 million GBP480 million GBP475 million GBP280 million
C	1800MHz holdings At least 4500 eligibility points	2x5MHz -	- 2x20MHz	GBP225 million GBP60 million
D	1800MHz holdings Less than 4500 eligibility points	2x5MHz - 2x10MHz*	- 2x20MHz -	GBP225 million GBP60 million GBP250 million

* Includes 2x10MHz coverage obligation block

Ofcom proceeded with the 800MHz and 2.6GHz spectrum auction in January 2013. Three took part in the opt-in round of the spectrum auction and submitted bids based on List D. It ultimately secured 2x5MHz in the 800MHz band at reserve price (GBP225 million).

Whilst this serves as a good example of a ‘flexible’ reservation for a fourth operator, our understanding is that it would be very challenging to incorporate floors into a non-combinatorial auction such as an SMRA.

4.4 Latin American countries that have auctioned the 700MHz band

Thus far, there have been three auctions of the 700MHz band in Latin America – Chile, Brazil and Argentina, as summarised in Figure 4-7 below.

Figure 4-7: 700MHz auctions in Latin America [Source: Aetha]

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/Generic	Caps	Reservations
Argentina Sequential multi-round auction (Oct 14)	700MHz 850MHz AWS 1.9GHz	2x45 2x3.75 2x45 2x17.5 ²⁴	3 lots of 2x10MHz 1 lot of 2x15MHz for both 700MHz and AWS bands (other bands available regionally)	Specific	50MHz for 3G spectrum 60MHz for 4G spectrum	2x10MHz (700MHz), 2x10MHz (AWS), 2x10MHz (1.9GHz though with frequencies split by region)
Brazil Auction (Oct 14)	700MHz	2x40	4 lots of 2x10MHz with one split into 3 regional lots, decreasing in a second stage to 2x5MHz blocks in the case of unsold spectrum	Specific	2x10MHz (increasing to 2x20MHz in the case of unsold spectrum in the main auction)	n/a
Chile Part beauty contest, part sealed-bid auction (Feb 14)	700MHz	2x35	2 lots of 2x10MHz 1 lot of 2x15MHz	Specific	n/a	n/a

²⁴ Total amount available as the sum of regional licences.

In addition to the above auctions, we note that in December 2012, Ecuador's National Telecommunications Council (Conatel) awarded the state-owned operator, CNT a partial assignment in the 700MHz band of 2x15MHz (along with 2x20MHz in the AWS band), thereby making it the first provider of LTE services in the country. We understand that no further allocations have been made as of yet. As this was an uncompetitive process, we do not regard it as a valid benchmark for Colombia.

As can be seen in Figure 4-7, the recent auctions in Chile, Brazil and Argentina, where larger 2x10MHz and 2x15MHz blocks were used, have not been in line with wider international precedent. As discussed in Section 3, there is a danger that such packaging can lead to inefficient outcomes. In Brazil for example, there was unsold spectrum, whilst in Chile and Argentina the auction formats used (which made the use of smaller blocks more challenging) presented significant disadvantages for bidders. In Chile, the 700MHz band is yet to be used by operators due to a legal dispute, whilst in Argentina bidders were exposed to significant aggregation risk as a result of the auction format.²⁵

Consequently, these auctions should not be considered as best practice. Rather, they serve as examples of the potential dangers of the larger block sizes and auction formats used.

We now explore the rules and outcomes of each of these auctions in more detail.

4.4.1 Argentina

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/Generic	Caps	Reservations
Sequential multi-round auction (Oct 14)	700MHz 850MHz AWS 1.9GHz	2x45 2x3.75 2x45 2x17.5	3 lots of 2x10MHz 1 lot of 2x15MHz for both 700MHz and AWS bands (other bands available regionally)	Specific	50MHz for 3G spectrum 60MHz for 4G spectrum	2x10MHz (700MHz), 2x10MHz (AWS), 2x10MHz (1.9GHz though with frequencies split by region)

In October 2014, Argentina's communications ministry (Secom) auctioned national licences for 4G spectrum in the 700MHz and AWS bands. In addition to this, regional 3G licences were awarded in the 850MHz and 1.9GHz bands²⁶. The lot structure is summarised in the table below.

²⁵ These are discussed in more detail in the country case studies below.

²⁶ These 3G licences were previously assigned to Arsat in 2012, but since reclaimed by the regulator as the spectrum was not being used.

Figure 4-8: Spectrum packaging and reported winners in the Argentinian auction
[Source: Policy Tracker²⁷]

Lot	Area	Bandwidth (MHz)	Frequencies (MHz)	Service ²⁸	Reported winner
1	National	2 x 10	1745 - 1755 / 2145 - 2155	SCMA	Airlink
1	National	2 x 10	738 - 748 / 793 – 803	SCMA	Airlink
1	I (North)	2 x 10	1895 - 1905 / 1975 – 1985	PCS	Airlink
1	II (Buenos Aires)	2 x 10	1890 - 1900 / 1970 – 1980	PCS	Airlink
1	III (South)	2 x 10	1880-1890 / 1960-1970	PCS	Airlink
2	II (Buenos Aires)	2 x 3.75	830.25 - 834 / 875.25 – 879	SRMC	Telecom Argentina
3	II (Buenos Aires)	2 x 5	1870 - 1875 / 1950 - 1955	PCS	Claro
4	I (North)	2 x 2.5	1892.5 - 1895 / 1972.5 - 1975	PCS	Claro
5	I (North)	2 x 2.5	1890 - 1892.5 / 1970 - 1972.5	PCS	Telecom Argentina
6	III (South)	2 x 5	1862.5 - 1867.5 / 1942.5 - 1947.5	PCS	Telecom Argentina
7	III (South)	2 x 2.5	1867.5 - 1870 / 1947.5 – 1950	PCS	Claro
8	National	2 x 15	1730 - 1745 / 2130 – 2145	SCMA	Telecom Argentina
8	National	2 x 10	713 - 723 / 768 - 778	SCMA	Telecom Argentina
9	National	2 x 10	1720 - 1730 / 2120 – 2130	SCMA	Claro
9	National	2 x 15	723 - 738 / 778 – 793	SCMA	Claro
10	National	2 x 10	1710 - 1720 / 2110 – 2120	SCMA	Movistar
10	National	2 x 10	703 - 713 / 758 – 768	SCMA	Movistar

As can be seen, all lots were frequency-specific. Operators were subject to caps of 50MHz for 3G spectrum and 60MHz for 4G spectrum.

Notably, Secom chose to reserve Lot 1 for new entrants – thus offering a guaranteed portfolio of spectrum across all bands at the reserve price. Whilst it has not yet been publicly announced, it is reported that this spectrum was acquired by internet service provider, Airlink. It is also worth noting that the auction format used in Argentina was unusual by international standards, as each lot was auctioned in succession rather than simultaneously. Such a format can create significant aggregation risk to bidders, and lead to inefficient outcomes. Bidders have less information available to them in sequential auctions, as they must guess what prices in future auctions may be, in order to determine their willingness to pay in the current auction. In a simultaneous auction however, bidders have information on the prices of all licences available to them *and* crucially are able to switch their bids between these licences in response to this information.

²⁷ Policy Tracker, ‘Argentina raises \$2.23 billion from AWS/700 MHz auction’, 11 February 2015.

²⁸ Unlike in many countries, the lots in Argentina were not awarded as technology-neutral. SCMA refers to Advanced Mobile Communications Services – this includes high data transfer services such as 4G/LTE. PCS (Personal Communications Services) and SRMC (Cellular Mobile Radio Services) include legacy technologies such as 3G/UMTS.

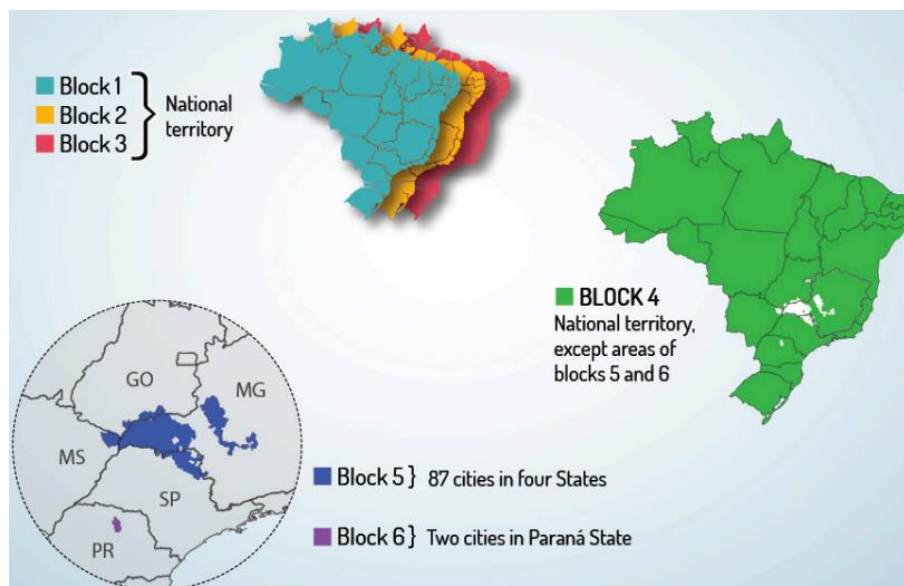
As a result, similar lots are more likely to sell at similar prices and bidders do not regret having bought too early or too late.

4.4.2 Brazil

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/Generic	Caps	Reservations
Auction (Oct 14)	700MHz	2x40	4 lots of 2x10MHz with one split into 3 regional lots, decreasing in a second stage to 2x5MHz blocks in the case of unsold spectrum	Specific	2x10MHz (increasing to 2x20MHz in the case of unsold spectrum in the main auction)	n/a

The 700MHz auction in Brazil was packaged into six specific lots, each with a bandwidth of 2x10MHz, but with three of the lots sharing the same frequencies on a regional basis (with one of them being close to national coverage). The coverage areas for each lot are summarised in the figure below.

Figure 4-9:
Coverage areas for blocks in Brazilian 700MHz auction
[Source: Anatel²⁹]



Bidders were subject to a cap of 2x10MHz. As a result of the lot sizes and cap, operators were not able to bid for more than one lot in the main stage of the auction. Given that Oi, the fourth largest operator in Brazil chose not to participate in the auction, there was no excess demand, with four lots sold at close to reserve price. Given the two unsold lots, the auction then proceeded to a secondary stage where the unsold lots were split into 2x5MHz blocks and the cap on bidders relaxed to 2x20MHz. No operators however chose to increase their demand. As a result, blocks 4 and 6 remained unsold.

The packaging of the spectrum was designed on the prior assumption of four or more interested bidders for a national (or near national) licence. In the wake of Oi's exit from the process and in the absence of a new entrant, a significant portion of a valuable resource is now left unsold.

²⁹ Anatel, 'The 700MHz auction in Brazil', 2014.

4.4.3 Chile

Auction	Bands	Spectrum for award (MHz)	Block sizes	Specific/Generic	Caps	Reservations
Part beauty contest, part sealed-bid auction (Feb 14)	700MHz	2x35	2 lots of 2x10MHz 1 lot of 2x15MHz	Specific	n/a	n/a

In Chile, 2x35MHz was made available in the band in what was the first allocation of the 700MHz band in Latin America under the APT700 band plan. The band was divided into three specific blocks, with no caps or reservations imposed.

Notably the award process was part beauty contest, part sealed-bid auction. Promoting network investment, connecting isolated regions and schools, and bridging the digital divide were express objectives of the regulator, such that key evaluation criteria including coverage, roaming and service-quality commitments were given precedence over auction receipts.³⁰ As a result each of the three incumbents acquired a block at prices deemed low by international standards (USD0.024/MHz/pop for the most expensive block). In this case, the assessment of bids was only relevant on the basis of pre-defined blocks since bidders could not make commitments without some guarantee of the bandwidth they may obtain.

Subjective processes such as this are now increasingly rare, as regulators seek to ensure transparency – in part to ensure that the results are not open to legal disputes. In Chile for example, despite being the first country in the region to auction the 700MHz band, operators are still unable to use the spectrum until the resolution of a lawsuit brought by the Conadecus (Chile's National Corporation for Consumers and Users), which seeks to invalidate the auction.³¹ The consumer group accuses the three main operators of spectrum hoarding, having acquired more than the 60MHz cap set by the Supreme Court in 2009. It also claims that the conditions of the auction – specifically those regarding investment, coverage requirements and rollout deadlines – were discriminatory and prevented smaller companies from competing.³² This is a clear example of the disadvantages of incorporating beauty-contest elements into an auction.

4.5 Summary

We now summarise some of the key trends observed in our benchmarks of past 700/800MHz auctions, noting in conjunction with block sizes, where certain learnings could be applied to Colombia.

4.5.1 Block sizes

The auctions in New Zealand and Australia, which involved an auction of all 2x45MHz available according to the APT700 band plan, featured a complete packaging of the band into 2x5MHz lots. In North America, spectrum in both the US and Canadian auction was also packaged into a majority of 2x5MHz and 2x6MHz blocks, given the irregularity of the band plan.

³⁰ GSM Association, Coleago Consulting, 'The cost of spectrum auction distortions', October 2014.

³¹ Pyramid Research, 'LTE on track to account for 4.2% of Latin America's total mobile subscriptions at year-end 2015', 7 May 2015.

³² TeleGeography, 'Conadecus threatens to take case to Supreme Court', 21 May 2015.

Out of 23 European 800MHz auctions, 14 have also featured such packaging of the band including a further six auctions where 2x5MHz blocks were used in conjunction with one or two 2x10MHz lots. We note that in most of these cases, such as in the UK, a 2x10MHz block was created for the purpose of attaching a coverage obligation.

In the vast majority of cases, blocks were sold as generic (i.e. non-frequency specific), and the positions within the band decided in a secondary assignment round. This ensures that in acquiring multiple blocks, there is minimal aggregation risk – i.e. contiguous spectrum holdings can still be obtained.

In light of these benchmarks, there is an extremely strong precedent for the use of 2x5MHz blocks.

We note that the recent auctions in Chile, Brazil and Argentina where larger 2x10MHz and 2x15MHz blocks were used, have not been in line with international best practice. For the reasons discussed in Section 3, there is a danger that such packaging can lead to inefficient outcomes. In Brazil for example, two of six lots in the 700MHz band were left unsold, even after reducing the block sizes of unsold spectrum to 2x5MHz in a secondary stage. Furthermore, the auction formats used in Chile (a part beauty contest, part sealed-bid auction) and Argentina (a sequential multi-round auction) were both unconventional by international standards for the following reasons.

In Chile, key evaluation criteria such as coverage, roaming and service-quality commitments were taken into account over and above auction receipts, such that the assessment of bids was only relevant on the basis of pre-defined blocks. Bidders for example could not make such commitments if they did not yet know the bandwidth they may obtain. Furthermore, we note that despite being the first country in the region to auction the 700MHz band, operators are still unable to use the spectrum until the resolution of a lawsuit brought by the Conadecus (Chile's National Corporation for Consumers and Users), which seeks to invalidate the auction. The consumer group accuses the three main operators of spectrum hoarding, having acquired more than the 60MHz cap set by the Supreme Court in 2009. It also claims that the conditions of the auction – specifically those regarding investment, coverage requirements and rollout deadlines – were discriminatory and prevented smaller companies from competing.³³ This is a clear example of the disadvantages of incorporating beauty-contest elements into an auction.

In Argentina, the sequential format of the auction meant that each lot was auctioned in succession rather than simultaneously (as would be the case in an SMRA auction). Bidders have less information available to them in sequential auctions, as they must guess what prices in future auctions may be, in order to determine their willingness to pay in the current auction. In a simultaneous auction however, bidders have information on the prices of all licences available to them *and* crucially are able to switch their bids between these licences in response to this information. As a result, similar lots are more likely to sell at similar prices and bidders do not regret having bought too early or too late. The Argentinian format could have therefore created significant aggregation risk to bidders and a greater potential for asymmetric prices. Clearly this risk would have been even greater with smaller lot sizes given such a format.

In the cases of Chile and Argentina, smaller block sizes were therefore less compatible with the auction formats used. In Colombia, we recommend that a more robust auction format such as an SMRA is adopted. This would allow operators to bid on multiple lots simultaneously, such that they are able to assemble their desired spectrum package across the multiple bands on offer. It is by far the most popular auction format to have been used in spectrum auctions.

³³ TeleGeography, 'Conadecus threatens to take case to Supreme Court', 21 May 2015.

4.5.2 Caps

In almost all of the reviewed auctions, caps on individual bands and/or another type of cap – either a total spectrum cap or a sub-1GHz cap have been implemented. For example, the 2012 Swiss multiband auction used individual caps on the 900MHz, 1800MHz and 2.1GHz bands together with a cap on all FDD frequencies which could be acquired, as well as a sub-1GHz cap. The combination of all these caps ensured that no operator could acquire more than 50% of total spectrum or in any one band below 2.6GHz.

In many of the 800MHz auctions carried out to date, the 800MHz caps were set at 2x10MHz. This ensured that at least three different operators could acquire spectrum in the band (given a total of 2x30MHz). The only country to have used a cap different to 2x10MHz was Denmark. Denmark opted for a 2x20MHz cap. We expect this was due to two of the existing operators forming a bidding joint venture which led to only three bidders being expected in the auction.

Notably in Canada, one of the implemented caps was applied only to operators with greater than 10% national market share (or 20% in the region of the licence). Of the five paired blocks available this ensured that only one of the three main operators could acquire more than two blocks. As such, this meant that a fourth operator could not be squeezed out, whilst maintaining competition for a second paired block.

4.5.3 Reservations

Of the past 700MHz and 800MHz auctions, reservations have been used in Argentina, Greece, Slovenia, Austria, UK (in the form of spectrum floors) and the Netherlands.

In addition to these, we note that the reservations have also been used in the following non-800MHz European auctions, as summarised in the table below.

Figure 4-10: Reservation in past non-800MHz European auctions [Source: Aetha]

Country	No. players before auction	Spectrum band	Spectrum available in award	Reservation
Netherlands (2010) CCA	3	2.6GHz	2x65MHz	Two lots of 2x20MHz
France (2010) Sealed bid	3	900MHz 2.1GHz	2x5MHz 2x15MHz	2x5MHz 2x5MHz
Belgium (2011) SMRA	3	2.1GHz	2x14.8MHz	2x14.8MHz
Hungary (2011) Sealed bid	3	900MHz Option: 1800MHz Option: 2.1GHz	2x15MHz 2x15MHz 2x15MHz	2x5MHz 2x15MHz 2x15MHz

The implementation of a reservation has been of particular success in France, where the spectrum gained by the new entrant Free, has created a credible fourth operator in the market – having gained a market share of 15% by the end of 2014³⁴. Other measures were also taken to support the entrant, covering amongst others, permitting 900MHz spectrum to be used for 3G, national 2G roaming and site sharing obligations for the other operators.

³⁴ FierceWireless: Europe, 'France's Iliad targets 25% mobile market share; quashes consolidation hopes', 13 March 2015.

Although no reservation was used in the Canadian 700MHz auction, we note that in the more recent AWS-3 auction held on 3 March 2015, 2x30MHz (60% of the auctioned spectrum) was reserved for ‘new entrants’ (as defined by a population coverage threshold)³⁵. On average, this has allowed the three challenger operators (Wind, Bragg and Videotron) to more than double their spectrum holdings prior to the AWS-3 auction, and will enable them to compete more effectively with the incumbent operators.³⁶

We note that there has been precedent for the implementation of a reservation in the Colombian 2013 AWS auction. In this auction both DirecTV and Avantel were considered new entrants and could bid for reserved blocks with a lower starting price³⁷.

In Slovenia, a reservation of 2x10MHz (two blocks of 2x5MHz) was made available in the 800MHz band for new entrants *or* existing operators with less than 15% market share. The reservation was designed such that eligible bidders could indicate their demand for the reserved blocks in their initial bids. If there was insufficient demand, one or more of these blocks could then be made available for all bidders.²² This ensured that Tušmobil, the country’s third largest operator (with a market share of ~12%) was able to gain both blocks of reserved spectrum, from which the dominant operators were excluded. Given a population of just two million people, Slovenia is the smallest European market with four players. It was therefore unclear if the market could sustain four competitive players. The regulator therefore decided that a reasonable objective for the auction would be to ensure that *at least* three operators gained sufficient spectrum to enable them to compete sustainably in the market. As a result, the auction also did not preclude outcomes in which four, or even more, operators win spectrum.

Notably, a number of comparisons can be drawn between the Slovenian and Colombian markets, given that both feature four network operators, with two dominant players and a consequently high degree of market concentration. The two largest operators, Mobitel and Si.mobil hold approximately 85% of the market, with the third and fourth operators holding ~12% and ~3% respectively.

Given the larger amount of spectrum available in the 700MHz band compared with the European 800MHz band, a similar reservation to that used in Slovenia, could be used to ensure that Avantel is able to acquire spectrum in the band.

³⁵ Industry Canada, ‘Auction of Spectrum Licences for Advanced Wireless Services in the Bands 1755-1780 MHz and 2155-2180 MHz (AWS-3)’, 20 April 2015.

³⁶ Policy Tracker, ‘Canadian AWS-3 spectrum sells for \$1.7 billion’, 10 March 2015.

³⁷ Larger operators were excluded from bidding on the basis of their dominant position in the outgoing voice market.

5 Conclusions

The Ministry of Information Technologies and Communications (MINTIC) and the National Spectrum Agency (ANE) have proposed a spectrum award process which includes large blocks (30MHz, 20MHz and 10MHz) of 700MHz spectrum, together with large blocks of spectrum in the 900MHz, 1900MHz and 2500MHz bands.

We have argued that a spectrum auction that uses a block size of 2x5MHz and allows the bidder to construct spectrum packages from 2x5MHz ‘building blocks’ will lead to a more efficient outcome. Multiples of 2x5MHz spectrum are efficient from a technical perspective because 5MHz is sufficient for efficient operation of LTE and because the bidder can construct any of the larger LTE carriers, or aggregate carriers across multiple spectrum bands, from multiple blocks.

The use of 2x5MHz blocks is efficient from an economic perspective, because it allows for the final combination of spectrum lots purchased by each operator to be aligned to their exact requirements and their willingness to pay. The final outcome of the spectrum award is therefore likely to allocate the spectrum to the highest value use. Such an outcome is likely to be far more efficient than an allocation of bands according to pre-designed spectrum assignments.

Through our benchmarks of past 700/800MHz auctions, we have found that there is a strong precedent for the use of 5MHz blocks in these, as well as other bands. The use of 2x5MHz blocks must be accompanied by the use of a suitable auction format that allows bidders to construct spectrum packages. The most commonly applied formats of this type are the SMRA or the CCA. The use of either of these formats would increase the efficiency of the proposed spectrum award process compared to the current proposals.

The use of an SMRA or CCA format does not prevent the regulator from exercising a reasonable degree of control to safeguard competition in the market for mobile services. Regulators have commonly applied caps and/or reservations in these auctions to ensure that no organisation can acquire an anti-competitive position as a result of its spectrum holdings. Furthermore, regulators have often included pro-competitive measures in auctions. In Slovenia for example, a reservation of 2x10MHz was put in place in the 800MHz band for new or existing operators with less than 15% market share. This ensured that a weaker player was able to gain crucial low-frequency holdings. Given the high market concentration in Colombia, and the previous precedent for the use of reservations in the 2013 AWS auction, we note that such a reservation in the 700MHz band may prove beneficial in promoting long-term competition in the provision of LTE services.