Study on comparability of frequency bands in different business models

Conducted for Ministerie van Economische Zaken

17th September 2010

Executive summary

The Netherlands Ministry of Economic Affairs is interested in the importance of sub 1 GHz spectrum to support the tentative objective of facilitating a fourth mobile network operator and has asked PA to consider the following five questions.

Question 1. Does the role and importance of the 800-, 900-, 1800-, 2100 MHz-, 2600 MHz-bands differ where different business models are operated? e.g. with a primary focus on a nationwide mass-market, or more of a niche strategy aimed at the SME market or on providing communications services at events for a limited time?

The role and importance of sub and supra 1 GHz spectrum bands varies according to the business model operated. A wide range of wireless telecommunication business models are in operation around the world and evidently certain frequency bands are more suited than others to support a particular business model.

The primary differences between sub and supra 1 GHz spectrum bands are the superior coverage and building penetration characteristics offered by sub 1 GHz spectrum bands. Operators with sub 1 GHz spectrum face lower network requirements and lower rollout costs. As such, sub 1 GHz spectrum bands are best suited for support of niche, low cost business models requiring broad coverage.

Supra 1 GHz spectrum bands, typically available in larger blocks capable of higher capacity and data rates, are best suited for support of niche, high data rate/high capacity business models. Operators with mass market business models, requiring a combination of broad national coverage as well as the ability to meet high capacity demands, for example in dense urban areas, tend to use a combination of sub and supra 1 GHz spectrum.

Question 2. If the answer to the first question is yes, then please distinguish between and elaborate on any technical and economic differences and similarities.

The role and importance of sub and supra 1 GHz spectrum bands varies according to the business model operated. There are economic and technical differences, and similarities between the spectrum ranges that account for this variance in role and performance. The primary differences are related to the technology that can be deployed at each band, the amount of spectrum available, the user experience, the size of the radio cell, the cost of deployment and the market value of the spectrum.

Overall, the sub-1 GHz spectrum bands are best suited for coverage and offer a lower cost option for operators to achieve that coverage. The supra-1 GHz bands are best suited for capacity, and are more likely to be able to offer higher speed services due to larger contiguous bands that could be made available. It is most unlikely to be cost effective to roll out a national network with supra 1GHz spectrum in contrast with operators that have access to sub 1GHz.

Question 3. Given the technological and market developments that can reasonably be expected during the next 5 to 10 years: Is it necessary for a mobile telecommunications service provider, with a nationwide mass-market ambition, and taking into account the common expectance of a return on investment by its shareholders, to have sub 1 GHz frequencies (800- and 900 MHz) at its disposal?

In today's market, access to sub-1 GHz spectrum may be essential to the success of a mobile telecommunications service provider with a nationwide mass-market ambition. Lack of access to sub 1 GHz spectrum will result in a material competitive disadvantage to a mobile operator with national mass market ambitions. As noted in response to Question 2, it is most unlikely to be cost effective to roll out a national network with supra 1GHz spectrum in contrast with operators that have access to sub 1GHz. This is one of the main reasons that new entrants operating at 2100 MHz today are typically compelled to enter into roaming agreements to achieve national coverage rather than embark on national build out programmes.

In the future, technical and market developments are in aggregate likely to increase the need for access to sub-1 GHz spectrum while also making access more feasible. The most noteworthy technical and market developments are:

- Significant increases in capacity requirements
- Spectrum refarming strategy decisions being taken by incumbents
- Network/spectrum/site sharing becoming increasingly common
- The opportunity to acquire new and additional sub 1GHz spectrum.

Question 4. Given the answers to the foregoing questions, is there, taking into account the Dutch government's tentative objective to facilitate a fourth mobile network operator, sufficient reason to treat sub 1 GHz frequencies differently from higher frequencies?

There is sufficient reason to treat sub 1 GHz frequencies differently from higher frequencies to support the tentative objective of facilitating a fourth mobile network operator. New entrants with nationwide, mass market ambitions face considerable disadvantages in their attempts to disrupt the market and compete successfully with the incumbents. The reasons are numerous but a lack of sub-1 GHz spectrum is one variable over which governments can exert some influence. There are many examples of regulators recognising that imbalances in spectrum holdings are an issue for new entrants and therefore have taken steps to treat sub- and supra-1 GHz spectrum differently.

Question 5. If your answer to question 4 is positive, then, seen in the light of your answer to question 3, is a cap of 2x20 MHz on sub 1 GHz frequencies proportionate to ensure the entrance of a fourth mobile network operator without hampering the incumbent mobile network operators too much?

A spectrum cap applying to the incumbents' ability to acquire spectrum will certainly support the entrance of a fourth operator if there is demand from investors to fund a new entrant. The proposed cap of 20 MHz should not unduly restrict incumbent operators although there is a risk this may limit a new entrant's ability to compete effectively, depending on the outcome of the auction.

Incumbent operators are in a strong position to reacquire their spectrum allocations in the 900 MHz band. This strength arises from the first mover advantage of having already invested in assets to meet national coverage and capacity requirements and already having a substantial customer base. These advantages are also applicable, albeit to a lesser extent, to spectrum in the 800 MHz band. As a result, incumbent operators are well placed to take up their full allocation of 2 x 20 MHz and a new entrant might be left with only 2 x 5 MHz. In this instance, in areas where a sub-1 GHz spectrum network provides the only coverage, a new entrant may be limited in it service offerings.

Alternatives to a spectrum cap are available if the Ministry wishes to mitigate this risk. These include:

- An amount of spectrum greater than 2 x 5 MHz could be reserved for the new entrant. This would provide the new entrant with a guaranteed spectrum allocation of e.g. 2 x 10 MHz of spectrum
- An auction process could be introduced which might lead to a new entrant and an incumbent partnering to purchase one of two blocks of sub-1 GHz spectrum. The new entrant would then most likely have either 2 x 10 MHz or more of the spectrum available
- The amount of spectrum the incumbents could be allowed to bid for could be reduced. For example, a cap of 15 MHz could leave the new entrant with 2 x 20 MHz of spectrum. This option would however create material drawbacks for the incumbents.

Contents

Executive summary **1**

1 Background to the questions **5**

1.1 The current mobile market in the Netherlands 5

1.2 Upcoming opportunities for a new entrant to the Dutch mobile market 5

1.3 OPTA would tentatively like to encourage a new entrant to join the Dutch mobile market 6

1.4 Questions posed by MEZA 6

2 Responses to the Ministry’s questions **8**

2.1 Wireless communication business models 8

2.2 Technical and economic characteristics of frequency bands 14

2.3 Requirement for sub-1 GHz spectrum 25

2.4 Treatment of sub-1GHz frequencies 29

2.5 Size of the cap on sub-1GHz frequencies 35

Appendix A: About PA Consulting Group **40**

1 Background to the questions

MEZA has asked PA Consulting to explore the importance of securing sub-1 GHz spectrum to a new entrant to the Dutch market. This section introduces the background to this request,

1.1 The current mobile market in the Netherlands

There are currently five operators in the Netherlands licensed to offer public wireless services. KPN, T-Mobile and Vodafone, hold licences in the 900, 1800, 2100 and 2600 MHz frequency bands, Ziggo and Tele2, hold newly acquired spectrum in the 2600 MHz band. Table 1 summarises these spectrum allocations.

The three incumbent mobile operators use their 900, 1800 and 2100 MHz holdings to support GSM and UMTS networks in national public networks. They, along with Ziggo and Tele2, are expected to deploy LTE in their newly acquired spectrum in the 2600 MHz band.

The wireless communications market in the Netherlands has undergone consolidation, with two mobile licence holders withdrawing from the market:

- KPN acquired Telfort in June 2005
- T-Mobile acquired Orange's spectrum and subscriber base in October 2007.

In August 2009 KPN handed back the 1800 MHz and 2100 MHz spectrum frequencies it gained along with the Telfort acquisition.

Allocations MHz		KPN	Tele2	T-Mobile	Vodafone	Ziggo
900 MHz		2 x 12.4	-	2 x 10	2 x 11.4	-
1800 MHz		2 x 20	-	2 x 31.8	2 x 5.2	-
2100 MHz	Paired	2 x 14.8	-	2 x 20	2 x 14.6	-
	Unpaired	1 x 5	-	1 x 10	1 x 5.4	-
2600 MHz		2 x 10	2 x 20	2 x 5	2 x 10	2 x 20

Table 1: Current spectrum allocations at 900, 1800, 2100 and 2600 MHz

Source: PA Consulting analysis of National Frequency Register of the Netherlands

1.2 Upcoming opportunities for a new entrant to the Dutch mobile market

Two upcoming auctions present opportunities for incumbent operators and new market entrants to acquire spectrum:

- Expiry and subsequent re-auctioning of incumbent 900 MHz licences, possibly in 2013
- Spectrum in the 800 MHz band released as a result of the digital dividend, possibly in 2017.

The three major MNOs can be expected to show great interested in securing spectrum in these bands. In addition, Tele2 and Ziggo who both secured spectrum in the recent 2600 MHz auction, can also be expected to show interest. It is also possible that further prospective new entrants with no current spectrum holdings could also participate in the auctions.

1.3 OPTA would tentatively like to encourage a new entrant to join the Dutch mobile market

The Ministry recently asked OPTA to conduct a study into the competitive environment in the Dutch mobile market. The report found that, whilst the mobile market is currently competitive, there is a risk that the three MNOs in the Dutch market could lessen the intensity of competition that they exert on each other. Also, given the possibility of a certain degree of risk of tacit collusion, there is a possibility of collective significant market power (SMP) arising, subsequent to the upcoming spectrum awards.

The report goes on to state that competition will increase when Tele2 & Ziggo, recent winners of 2600 MHz spectrum, enter the market. The report raises the possible risk that these two operators might not be able to evolve into fully-fledged competitors if limited to their 2600 MHz frequency holding. MEZA would like to explore the importance of securing sub-1 GHz spectrum to a new entrant to the Dutch market.

1.4 Questions posed by MEZA

In order to explore the importance of sub-1 GHz spectrum to a new entrant, MEZA have posed five questions to be addressed within this report:

Question 1: Does the role and importance of the 800 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2600 MHz bands differ where different business models are operated? E.g. with a primary focus on a nationwide mass-market, or more of a niche strategy aimed at the SME market or on providing communications services at events for a limited time?

Question 2: If the answer to the first question is yes, then please distinguish between and elaborate on any technical and economic differences and similarities.

Question 3: Given the technological and market developments that can reasonably be expected during the next 5 to 10 years: Is it necessary for a mobile telecommunications service provider, with a nationwide mass-market ambition, and taking into account the common expectance of a return on investment by its shareholders, to have sub-1 GHz frequencies (800- and 900 MHz) at its disposal?

Question 4: Given the answers to the foregoing questions, is there, taking into account the Dutch government's tentative objective to facilitate a fourth mobile network operator, sufficient reason to treat sub-1 GHz frequencies differently from higher frequencies?

Question 5: If your answer to question 4 is positive, then, seen in the light of your answer to question 3, is a cap of 2x20 MHz on sub-1 GHz frequencies proportionate to ensure the entrance of a fourth mobile network operator without hampering the incumbent mobile network operators too much?

The remainder of this report provides a response to these questions.

2 Responses to the Ministry's questions

The section presents PA's responses to the questions that the Ministry has asked us to consider.

2.1 Wireless communication business models

Question 1: Does the role and importance of the 800 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2600 MHz bands differ where different business models are operated? E.g. with a primary focus on a nationwide mass-market, or more of a niche strategy aimed at the SME market or on providing communications services at events for a limited time?

The role and importance of sub and supra-1 GHz spectrum bands varies according to the business model operated. A wide range of wireless telecommunication business models are in operation around the world and evidently certain frequency bands are more suited than others to support a particular business model. This section examines business models in three major groups:

- Niche, low cost business models requiring broad coverage
- Mass market, nationwide business models
- Niche, high data rate/high capacity business models.

The primary differences between sub and supra-1 GHz spectrum bands, covered in detail in the answer to Question 2, are the superior coverage and building penetration characteristics offered by sub-1 GHz spectrum bands. As a result of these characteristics, operators with sub-1 GHz spectrum require fewer base stations and supporting passive infrastructure elements in order to achieve their desired network coverage. These reduced network requirements translate to lower rollout costs. As a result, operators with lower cost business models requiring broad coverage tend to use sub-1 GHz spectrum where it is available.

Whilst each block of sub-1 GHz spectrum offers the same capacity as the same sized block of supra-1 GHz spectrum, larger blocks tends to be available at the higher frequency. These larger blocks offer greater levels of capacity and, when utilised for LTE deployment, higher download rates. As a result of these characteristics, operators with business models requiring higher data rates and capacity but a smaller emphasis on coverage tend to use supra-1 GHz spectrum where it is available.

Operators with mass market business models, requiring a combination of broad national coverage as well as the ability to satisfy localised areas of high capacity demand, for example in dense urban areas, tend to use a combination of sub and supra-1 GHz spectrum.

Figure 1 below illustrates the trade-off between high coverage and high data rates/capacity characteristics between the frequency bands is illustrated.

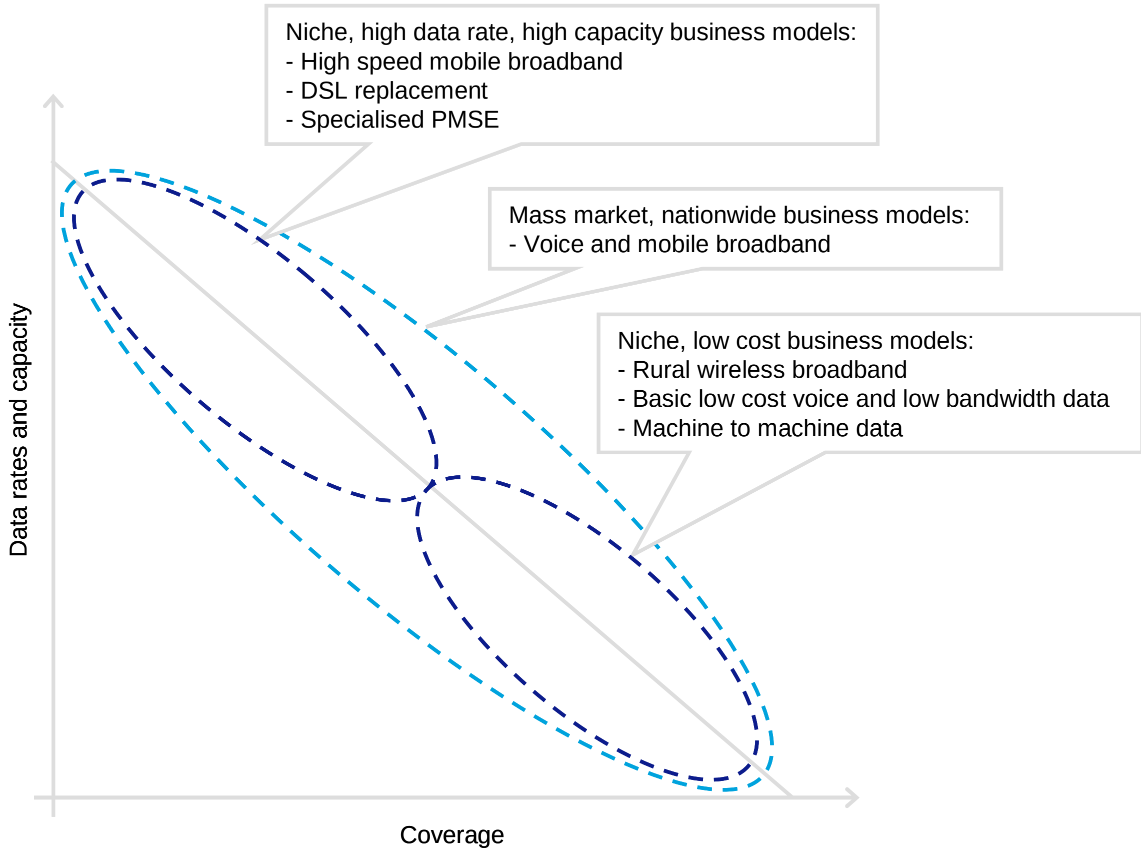


Figure 1 : Spectrum characteristics

Source: PA Consulting analysis

2.1.1 Niche, lower cost business models covering wide areas benefit most from sub-1 GHz spectrum

Aggregated traffic demand for the services offered by operators with low cost business models can be expected to be limited. These business models benefit from access to lower frequencies which enable low cost network rollout, maintenance and upgrade. This low cost base enables an operator to price its services at a level at which consumers are willing to accept the limitations of relatively low bandwidth services, or provide services where these limitations do not apply.

Examples of this type of operator in the 800 and 900 MHz bands in Europe are uncommon as:

- The 800 MHz band has not been, or has only very recently been released
- The 900 MHz band, which has been in common use for mobile operators, is regarded as high value and has therefore been secured for more profitable mass market mobile services.

However there are examples of operators using frequencies below 800 MHz to offer these services including:

- Rural wireless broadband services
- Basic low cost voice and low bandwidth data services
- Machine-to-machine services.

Operators with rural wireless broadband services commonly offer services in areas in which fixed line DSL services are not available. The download speeds are typically notably inferior to DSL services but operators gain market share due to the lack of alternative technologies deployed in rural areas. For example:

- Finland's Digita Oy, primarily a television and radio broadcaster, has been offering wireless broadband in the 450 MHz band since 2007. The network covers 99% of the population in mainland Finland. Digita Oy describes the benefit of its spectrum as having "a low frequency range so it is possible to cover broad geographical areas with a single base station. This means that the network lends itself well to use as a connection network covering all parts of Finland"[1]. Digita Oy regards its target users as homes in remote areas, holiday cottages, outdoors enthusiasts such as boaters and companies wanting low cost services for mobile or remote workers in the logistics or forestry industries.
- Net1 has been offering mobile broadband services in Sweden, Norway and Denmark using CDMA technology in the 450 MHz band since 2003. It has broader network coverage than its mobile competitors - for example in Sweden it covers 90% of the land mass compared with the MNOs' 50%. According to Net 1 this allows "25 times the coverage per transmitter than GSM and UMTS-based systems that send on 900 MHz, 1800 MHz and 2100 MHz".[2] In addition, the advantageous propagation features of the network mean that Net1 can build out its 3G network to locations which were not previously financially viable.

Operators with basic low cost voice and low bandwidth data services have similar offerings to their mass market competitors but with a narrower range of services and lower data rates. They differentiate themselves either by targeting locations that are underserved by their competitors or by offering the services at lower prices. For example, Portugal's Zapp launched wireless broadband services in 2004 using CDMA 450 technology. The network covers 95% of the population and offers a peak download data rate of 1.4 Mbps, although the user experience will be significantly lower in practice. The estimated infrastructure investment required for the rollout of the network was USD160 million to provide 95% population coverage, enabling it to cost-effectively target users outside of Portugal's main urban centres[3].

Business models targeting machine-to-machine services are characterised by the need for good coverage along with the deep building penetration required to reach equipment permanently situated within offices or homes. This business model tends to generate low levels of regular traffic, charged at very low tariffs in comparison to mobile voice services sold to consumers. The resulting relatively low levels of revenue therefore require a low cost base in order to generate a suitable margin for the business to be viable. For example, KPN is currently rolling out a CDMA 450 network designed to serve the machine-to-machine market. The CDMA network is entirely separate to KPN's existing networks. KPN expects the business to generate low levels of revenue with less than half a megabit of

[1] http://www.450laajakaista.fi/9102/English

[2] http://www.net1.se/omnet1/teknik.aspx

[3] http://www.mobilecomms-technology.com/projects/radiomovel/

data per month per machine. Due to the low cost base facilitated by the 450 MHz spectrum band, KPN expects to achieve high margins over a long period of time.[4]

2.1.2 Mass market, nationwide business models benefit most from a mix of spectrum assets

Mass market, nationwide operators with voice and mobile broadband offerings benefit most from access to both lower and higher frequencies. Lower frequencies can be expected to support cost effective coverage for rural areas. Larger spectrum allocations, typically available at higher frequencies, support high bandwidth and traffic demand in areas of high population density.

To examine mass market, nationwide operator's requirement for both sub and supra-1 GHz spectrum it is helpful to consider how the operators have acquired their spectrum over time.

Early entrants to mobile markets were typically allocated spectrum in the 900 MHz band by national regulators. The low penetration levels during these formative years allowed these early entrants to concentrate their efforts on achieving wide coverage without having to face any significant capacity constraints. Following a successful period of customer acquisition, operators had to contend with capacity constraints as their customer base grew, particularly in areas of high population density. These capacity constraints led many operators to lobby for additional spectrum that was met with further allocations, typically at higher frequency bands.

The case of T-Mobile in Germany is illustrative of how established mass market, nationwide operators have built their spectrum assets with both sub and supra-1 GHz spectrum. As can be seen in Figure 2, representing the timeline of its spectrum asset acquisition, T-Mobile started with 25 MHz in the 900 MHz band. The operator used the favourable propagation characteristics of this band to roll out its nationwide network. As penetration rates grew towards the end of the 1990s, further spectrum was required to meet the growing levels of aggregated traffic resulting from a larger subscriber base. Following lobbying by T-Mobile, the regulator made spectrum in the 1800 MHz band available which T-Mobile acquired. The high profile 3G auctions in 2000 represented a further opportunity to acquire spectrum. T-Mobile secured a large block of spectrum which would be used to satisfy the additional capacity requirement and demand and higher peak data rates created by 3G data services. The recent 2010 "big bang" auction, in which spectrum in a number of bands was made available, represented a further opportunity to meet the demands of a step change in capacity requirements driven by nationwide LTE rollout plans and a significant increase in mobile broadband demand. T-Mobile took this opportunity to meet the nationwide increase in capacity demand expected in the near future.

[4] Gerard van der Hoeven, strategic business developer at KPN

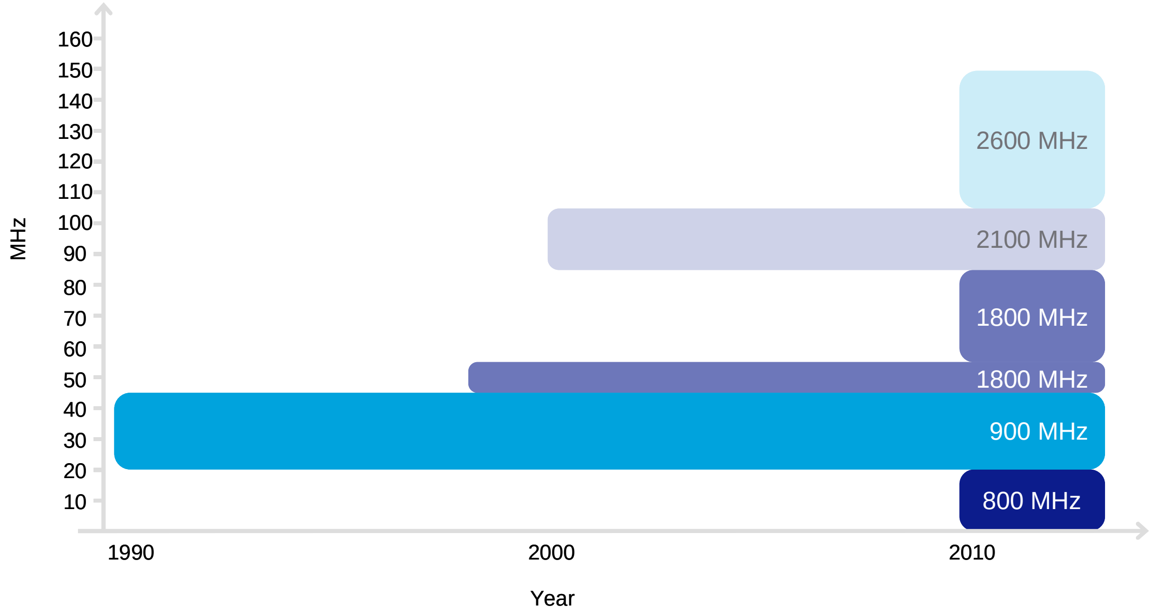


Figure 2 : T-Mobile Germany, spectrum asset acquisition timeline

Source: http://www.bundesnetzagentur.de/cae/servlet/contentblob/138210/publicationFile/3726/DiscussionPaperID15294pdf.pdf

Conversely, late entrants to mobile markets started with whichever spectrum band was made available at that time. This spectrum has, until recently, only been available in the higher bands. As detailed in response to Question 2, late entrants with mass market nationwide ambitions face notably higher network rollout costs if confined to supra-1 GHz spectrum bands. Many of these have made use of national roaming agreements to achieve national coverage as illustrated in Table 14 in section 2.4.2. Having launched their services, these new entrants have subsequently sought to acquire additional spectrum in the sub-1 GHz bands.

P4 in Poland for example, started with spectrum in the 3G, 2100 MHz band. It subsequently attempted to secure sub-1 GHz spectrum, successfully acquiring 2 x 5 MHz of spectrum in the 900 MHz band in 2008. Figure 3 below illustrates the timeline of spectrum acquisition for P4.

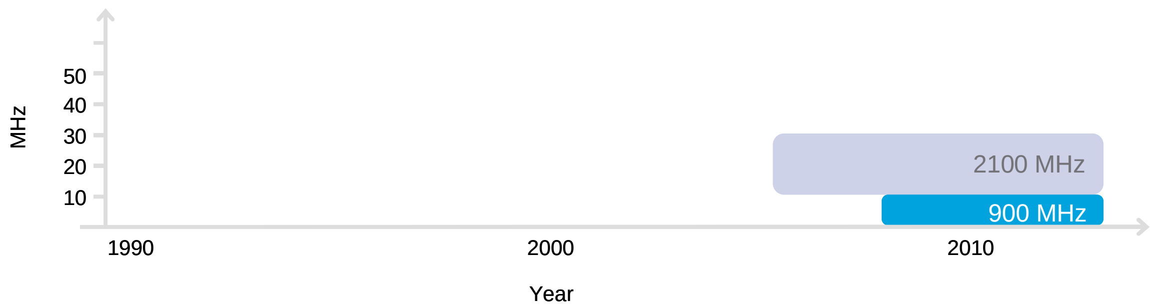


Figure 3 : P4 Poland, spectrum asset acquisition timeline

Source:http://www.gsmworld.com/roaming/index.html

Germany's third largest operator E-Plus also attempted to secure sub-1 GHz spectrum in the recent auctions. Prior to the auction, E-Plus stated a clear interest in 800 MHz spectrum with its pre-auction positioning statement "For increasing its broadband data network coverage, the most cost effective way would be to utilize 800 MHz frequencies."[5] With spectrum being auctioned in a range of bands, E-Plus viewed it as an opportunity to "upgrade its network to higher capacity and improve data coverage."[6] Bids for spectrum in the 800 MHz band rose to a level deemed too high by E-Plus, prompting a withdrawal from the auction in the final rounds of bidding. Instead of relying on sub 1 GHz spectrum to achieve national coverage, E-Plus has subsequently stated a desire to enter a national roaming agreement with one of its competitors. E-Plus did, however, secure supra 1 GHz spectrum in the auction. It should be noted that spectrum in these higher bands will not be used for achieving national coverage but will be deployed in locations of high capacity demand.

While E-Plus was not successful in its attempts to acquire 800 MHz spectrum at the auction, the other major German operator without substantial sub-1 GHz spectrum in Germany, Telefonica O2, secured 2 x 10 MHz.

This examination highlights that early entrants to the market typically started with lower bands and have gone on to acquire higher frequency bands at a later stage to meet growing traffic demand. Later entrants have typically had to start with higher frequency bands but have sought to acquire lower frequency bands when available or have been compelled to enter into national roaming agreements to achieve national coverage. Access to both sub-1 GHz spectrum and supra-1GHz spectrum appears to be very important to support a mass market, nationwide operator's business model.

2.1.3 Niche, high data rate/high capacity business models require the larger allocations available at higher frequencies

Niche, high data rate/high capacity business models require spectrum capable of supporting high speed, high capacity services cost effectively. Demand met by these models are typically location specific and so don't need wide coverage ranges. The niche, targeted nature of these business models means that achieving high levels of coverage is less of a priority. Higher frequency spectrum bands support these requirements. Examples of these types of business models in the marketplace today include:

- High speed mobile broadband services
- DSL substitution services
- Programme making and special events services.

Mobile broadband service providers offer fast connectivity to customers typically offered using dongles or chipsets in laptops as well as premium smartphones. The coverage offered for these services is typically restricted to densely populated urban areas. Much of the 2600 MHz allocated thus far in Europe has been secured by operators for these types of services. In addition, significant market players have sought to encourage the development of such operators. For example, Intel has invested in 2600 MHz capacity in Sweden to encourage the adoption of its wireless chipsets in laptops and other devices.

---

[5] KPN position paper on German spectrum auction

[6] KPN position paper on German spectrum auction

Clear in the USA, the newly formed operator created by Clearwire and Sprint, offers 4G mobile broadband using WiMAX in the 2.5 GHz[7] spectrum band. Clear, offering 4G services since 2009, is confident of the capacity and bandwidth capability of its services making statements such as "No streaming movie, no video game or video chat can choke it"[8].

Wireless DSL providers offer a wireless like-for-like alternative to fixed line DSL and therefore require adequate spectrum to offer comparable data rates to DSL. These high speed services are typically offered in specific locations of high population density such as business districts and city centres. Ci-Net offers city centre fixed wireless access to business users in the UK. The service offers an uncontended connection of up to 20 Mbps, comparable to bandwidth offered over DSL.[9] Ci-Net secured spectrum in the 5.8 GHz band in 2004 and uses technology similar to WiMAX.

Programme making and special events (PMSE) services represent another business model that fits within this category. PMSE often requires temporary wireless capacity to manage broadcast traffic in local areas. These services typically only require small coverage areas but may be carrying large volumes of traffic and demanding high data rates. For example, Ofcom, the UK regulator, intends to reserve a portion of the 2600 MHz spectrum band for use by broadcasters during the 2012 London Olympic Games for PMSE. This band is ideal for the high capacity, high bandwidth applications used by broadcasters.

2.2 Technical and economic characteristics of frequency bands

Question 2: If the answer to the first question is yes, then please distinguish between and elaborate on any technical and economic differences and similarities.

As stated in response to Question 1, the role and importance of sub and supra-1 GHz spectrum bands do vary according to the business model operated. There are economic and technical differences, and similarities, between the spectrum ranges that account for this variance in role and performance. Table 2 summarises these differences.

	800 MHz	**900 MHz**	**1800 MHz**	**2100 MHz**	**2600 MHz**
Technology Options	3GPP and WiMAX	3GPP only			3GPP and WiMAX
Amount of spectrum available	Mobile operators are likely to have access to smaller contiguous bands		Mobile operators are likely to have access to larger contiguous bands		

[7] Equivalent to the European 2.6 GHz band but includes an additional 4 MHz of spectrum

[8] http://www.clear.com/

[9] http://www.ci-net.com/files/files/product%20datasheets/Redkite%20Burstable%20-%20Version%20for%20Web%20and%20email.pdf

	800 MHz	900 MHz	1800 MHz	2100 MHz	2600 MHz
User experience	Lower speeds and less capacity available		Higher speeds and more capacity available		
Cell size	Greater cell size		Smaller cell size		
Cost	Lowest cost deployment of national network		Deployment up to 15 times more expensive than sub-1 GHz		
Value of spectrum	High value		Lower value		

Table 2: Summary of technical and economic issues related to spectrum bands

Source: PA Consulting analysis

Overall, the sub-1 GHz spectrum bands are best suited for coverage, and offer a lower cost option for operators to achieve that coverage. The supra-1 GHz bands are best suited for capacity, and are more likely to be able to offer higher speed services due to larger contiguous bands that could be made available. It is most unlikely to be cost effective to roll out a national network with supra-1GHz spectrum in contrast with operators that have access to sub-1GHz.

The remainder of this section considers each of these categories in greater detail.

2.2.1 Operators have a similar range of technology choices available in the sub and supra-1 GHz bands

Spectrum owners have a variety of options for technologies that may be deployed in the 800, 900, 1800, 2100 and 2600 MHz frequency bands. Of the bands under examination:

- LTE is available at 2600 MHz and 800 MHz, and is likely to be available at 900 and 1800 MHz soon. It may also supersede UMTS at 2100 MHz but not in the near future
- UMTS is available at 900 and 2100 MHz, and soon to be available at 1800 MHz, but is unlikely to be available at 800 and 2600 MHz
- WiMAX is available at 2600 MHz, and is likely to be available at 800 MHz within 2-3 years. However there are no plans for WiMAX to be available at 900, 1800 or 2100 MHz.

This remainder of this section summarises the technologies and the timeframes in which the equipment will be available for the two major technology standards groups, 3GPP and WiMAX.

3GPP standards group

The 3GPP family includes:

- GSM, first deployed in the Netherlands in 1992
- UMTS technology, launched in the Netherlands in 2004

- Long Term Evolution (LTE), generally considered as 4G technology.[10]

GSM technology is implemented in the 900 MHz and 1800 MHz frequency bands by all of the Netherlands' three major mobile network operators. GSM has been superseded by other variants in the 3GPP family, and is not considered as a viable technology option for future deployment.

The Netherlands' three incumbent mobile operators have implemented UMTS in the 2100 MHz band. However it is likely that the mobile operators will seek to use this technology in other frequencies. Table 3 shows the availability of UMTS network equipment and handsets at different frequencies.

Frequency Band	Network Availability	Handset Availability
800 MHz	Not planned	Not planned
900 MHz	Now	Now
1800 MHz	2011	2011
2100 MHz	Now	Now
2600 MHz	Not planned	Not planned

Table 3: Timetable for availability of UMTS network equipment and handsets

Source: PA Consulting analysis based on industry source

UMTS networks are currently in operation in most countries around the world at 2100 MHz. Moves towards technology neutrality have opened up other bands for UMTS. EC decision 2009/766/CE came to the conclusion that cohabitation is possible between UMTS and GSM deployments at both 900 and 1800 MHz.[11] Operators are starting to use the 900 MHz spectrum to extend UMTS reach to rural areas.[12] The proximity of 1800 MHz spectrum to 2100 MHz has encouraged operators to focus their attention on 900 MHz spectrum for use of UMTS. However operators are now beginning to reconsider this option, attracted by the spectrum available at 1800 MHz that could be used to manage growing mobile broadband traffic.[13]

Both the 800 and 2600 MHz bands are recognised as potential operating bands for UMTS.[14] However the development of a profile does not automatically lead to development of and demand for infrastructure, and PA is unaware of plans to develop network equipment and handsets for use in

---

[10] LTE is a member of the IMT-2000 technology family of standards. LTE Advanced is under the banner of the IMT-Advanced family.

[11] "Common Decision of 16 October 2009 on the harmonisation of the 900 MHz and 1 800 MHz frequency bands for terrestrial systems capable of providing pan-European electronic communications services in the Community", Official Journal of the European Union, 20/ 10/ 2009

[12] In Romania for example, Vodafone has deployed a UMTS 900 MHz network focused on rural areas that covers almost 60% of the land area and 38% of the population, extending UMTS coverage from the 17% land area and 52% of the population covered using 2.1GHz spectrum https://www.vodafone.ro/personal/serviciile-mele/reteaua-vodafone-acoperire/calitatea-retelei/index.htm

[13] Orange is planning a trial of UMTS 1800 MHz in November 2010. "Groundbreaking HSPA pilot in the 1800 MHz band to boost the UMTS1800 ecosystem" Orange/ Ericsson press release, 03/08/2010

[14] ETSI TS25.101 v.9.4.0 Table 5.0

those bands. Instead, operators are intending to use these bands to deploy the successor technology to UMTS, known as LTE. LTE has the advantage that it can be deployed in a variety of channel bandwidths from 1.4 MHz to 20 MHz, whereas UMTS supports only a 5 MHz channel bandwidth. Table 4 shows the estimated timetable for availability of network equipment and handsets for LTE in different bands.

Frequency Band	Network Availability	Handset Availability
800 MHz	2010	2011
900 MHz	2011	2011
1800 MHz	2011	2011
2100 MHz	2011	2011
2600 MHz	2010	2010

Table 4: Timetable for availability of LTE network equipment and handsets

Source: PA Consulting analysis based on industry sources

Mobile operators in Europe are gearing up to deploy LTE in the 2600 MHz band as it comes available. Operators and vendors are working together to deploy in other bands as well. Telenor and Tele2 are cooperating to deploy LTE at 2600 MHz, and will also combine their 900 MHz spectrum assets to support LTE. However only TeliaSonera has launched a service, introducing LTE in Norway and Sweden in December 2009.

At present only Germany has successfully auctioned its 800 MHz spectrum. One of the auction winners, Vodafone, is expected to begin deployment of its LTE network in 2010, with a target of a 1,500 base station network by the end of 2011.[15] However trials of LTE in 800 MHz spectrum are starting now in other countries.[16] With the proximity of 900 MHz to 800 MHz, and the incumbents' initial deployments of UMTS in 900 MHz bands, demand for LTE at 900 MH in the short term may be muted. Similarly the 1800 MHz band may be used for LTE in the medium term.[17]

LTE equipment using TDD spectrum is very likely to be available in significant volumes as a result of demand from network operators in China requiring an evolution path for TD-SCDMA, but availability is likely to be later than LTE in FDD.[18]

[15] http://www.huawei.com/news/view.do?id=11246&cid=42

[16] For example trials are beginning in the UK, mostly in rural or less densely populated areas of the country. O2 is planning a trial of mobile services in Carlisle using LTE in the 800 MHz band (Digital Dividend Update Update, Global Mobile Suppliers Association, 28/07/2010).

[17] There are trials planned of LTE at 1800 MHz using FDD spectrum by Telstra in Australia (GSM/ 3G Market/ Technology Update, Global Mobile Suppliers Association, 26/08/2010).

[18] China Mobile, which is rolling out a TD-SCDMA network, is cooperating on LTE tests with Verizon and Vodafone. In Poland CenterNet and Mobyland are using 1800 MHz spectrum to test LTE TDD in Poland (GSM/ 3G Market/ Technology Update, Global Mobile Suppliers Association, 26/08/2010). Global Mobile Suppliers Association Information Paper claims that LTE TDD is “promising to be commercially available 2009-10”, but PA expects it be at least 2 years later than LTE FDD.

WiMAX technology

WiMAX is now incorporated into the IMT-2000 family alongside more established technologies such as UMTS – ITU World Radiocommunication Conference-07 (WRC-07) saw mobile WiMAX included in the IMT-2000 family as the sixth technology standard. WiMAX uses an air interface based on Orthogonal Frequency-Division Multiple Access (OFDMA) technology, in common with LTE technology. The two most common operational WiMAX standards are:

- 802.16d, which supports only fixed services, and is available for use with both paired and unpaired spectrum
- 802.16e, extending capability into mobile services, but is often used to support fixed services because it offers better performance than 802.16d. It is not compatible with 802.16d.

The standard for the next generation of WiMAX, 802.16m, promises higher speeds, with mobile data rates of up to 100 Mbps, enabling direct competition with LTE.

The WiMAX Forum document "WMF-T21-001-R010v01 Rel 1.0 Mobility Profile Requirements" indicates only three band classes, 2300–2400 MHz, 2496–269 MHz and 3300–3800 MHz for WiMAX operation at present.[19] An IEEE update on 802.16m indicates that spectrum in the range 698 – 862MHz is intended to be a WiMAX band class (band class 7) for Mobile WiMAX release 1.5.[20]

At present there are no WiMAX networks deployed in the European Union in any of the bands under consideration. However the winners of TDD spectrum auctioned in the 2600 MHz band are likely to be considering WiMAX as an option for deployment. Only TDD versions of WiMAX 802.16e are available for 2600 MHz as well as a profile at 2300 MHz that is used in South Korea. However the WiMAX Forum has defined FDD profiles for WiMAX 802.16e and vendors are considering developing FDD versions for 2600 MHz. Table 5 summarises network and handset availability for WiMAX technology.

Frequency Band	Network Availability	Handset Availability
800 MHz	Future in line with 802.16m	Future in line with 802.16m
900 MHz	Not planned	Not planned
1800 MHz	Not planned	Not planned
2100 MHz	Not planned	Not planned
2600 MHz (TDD)	Now	Now

Table 5 : Timetable for availability of WiMAX 802.16e network equipment and handsets

Source: PA Consulting analysis based on industry sources

[19] WMF-T21-001-R010v01 Rel 1.0 Mobility Profile Requirements

[20] http://ewh.ieee.org/r6/scv/comsoc/Talk_032509_WiMAXUpdate.pdf

2.2.2 The quantity of spectrum available varies between sub and supra-1 GHz bands

Greater quantities of spectrum are available at the higher frequency bands. Supra-1GHz spectrum bands have 2-3 times more spectrum available than the sub-1GHz spectrum bands. Table 6 shows the amount of spectrum that may be available in each band, assuming the Netherlands follows approaches taken in other European countries.

MHz	800 MHz[21]	900 MHz	1800 MHz	2100 MHz	2600 MHz
FDD spectrum MHz	2 x 30	2 x 35	2 x 75[22]	2 x 60	Max 2 x 65[23]
TDD spectrum MHz	-	-	-	20	Min 50
Total spectrum available MHz	60	70	150	140	190

Table 6: Spectrum available at each band

Source: MEZA, OPTA

The amount of spectrum available, as well as the level of competition for that spectrum, determines the amount of contiguous spectrum available to an operator. In a country such as the Netherlands it is likely that there will be competition between the three incumbent operators and one or two new entrants for spectrum resources. If operators are able to bid similar amounts, spectrum is likely to be divided between at least three and perhaps four operators. In the sub-1 GHz frequencies, operators may be able to secure at least 5 MHz and at most 10 MHz of contiguous spectrum. With greater quantities of spectrum in the supra-1 GHz bands, operators are more likely to be able to secure contiguous bands of at least 10 or even 20 MHz of paired spectrum.

2.2.3 The band sizes available will have an impact on the user experience

This availability of contiguous spectrum may have an impact on the user experience of mobile services, and the types of service available. In particular, should an operator be restricted to a 5 MHz channel then this may adversely affect some services and user experience. Table 7 shows peak data rate, network capacity and average edge of cell data rate for 5 MHz and 20 MHz channels.

Parameter	5MHz channel	20MHz channel
Peak data rate[24]	36.7Mbit/s	149.8Mbit/s

[21] Assumed to be in the range 791-821 MHz paired with 832-862 MHz

[22] 2x75 MHz is the maximum available in this band. Of this, 2x2.5 MHz is currently reserved for licence-free low power mobile communication in the Netherlands.

[23] Although the 2600 MHz profile indicates a maxmimum of 2 x 70 MHz of FDD spectrum available, the Netherlands has implemented guardbands which has reduced the amount of spectrum available to 2x65 MHz. Lot 38 is a guardband for the adjacent radio-astronomy spectrum, and is assigned to the owner of lot 13/37 (Tele2).

[24] "LTE for UMTS", Holma & Toskala, Table 9.3 for 64QAM with 2x2 MIMO

Parameter	5MHz channel	20MHz channel
Average spectral efficiency[25] / Average network capacity	~1.7bit/s/Hz 8.5 Mbits / sector	~1.7bit/s/Hz 34 Mbits / sector
Average edge-of-cell spectral efficiency[25] / average edge-of-cell data rate	~0.07bit/s/Hz 0.35 Mbit/s	~0.07bit/s/Hz 1.4 Mbit/s

Table 7: Peak and average data rates for 5 and 20 MHz channels for LTE

Source: "“LTE for UMTS”, Holma & Toskala, Table 9.3

This illustrates a notable impact on service speed. Average edge-of-cell data rate decreases from 1.4Mbit/s per user to 0.35Mbit/s per user or a quarter of the data rate of a 20 MHz channel.

The likely impact on capacity can also be estimated. Assuming:

- An urban customer density of about 1,500 subscribers per cell, i.e. 1 sector on a 3-sector macro-cell, based on an urban population densities of 10,000 people / km^2
- LTE urban cell range at 800 MHz of ~1km (based on Hata model, ETSI TR43.030 Appendix B.1), resulting in a cell size of ~1.3 km^2 (based on a hexagonal grid layout)
- A target market share of 20%.

This suggests an urban customer density of ~1,500 subscribers per cell (i.e. 1 sector on a 3-sector macro-cell). The average cell capacity for a 5 MHz channel is ~8.5Mbit/s (from table above). Even if only 1 in 50 customers is active during the busy hour, this is still only ~300kbit/s on average per active subscriber, which may restrict some services and user experience (particularly if, as expected, download speeds and user expectations increase over time).

Data rates of at least 1–2 Mbit/s are likely to be needed to offer higher-quality video services to cellular users with terminal screens larger than today’s mobile phones, such as laptops and tablets. Operators that fail to secure more than 5 MHz contiguous spectrum in the lower bands are unlikely to be able to offer higher-quality video services to mobile users, or indeed fixed users who happen to be at the edge of the cell.

One of the key points of migrating to LTE is its ability to support higher channel bandwidths (up to 20 MHz), thus delivering higher data rates to users and a “truer” mobile broadband experience. Incumbents will be keen to make use of these higher channel bandwidths and would like to acquire sub-1GHz spectrum in the largest contiguous blocks possible in order to be able to deploy these larger channel bandwidths.

In fact, LTE using 5 MHz channels offers little advantage over today's HSDPA services. A 5 MHz spectrum allocation using LTE supports services equivalent in speed to HSDPA+:

[25] “LTE for UMTS”, Holma & Toskala, Figure 9.12 for macro case 1, 2x2 MIMO

- The latest releases of HSPA+ have spectral efficiency in the region of 1.45 bits/s/Hz compared with LTE with an average spectral efficiency of ~1.75 bits/s/Hz
- Downlink peak data rate for HSPA+ gets up to ~42Mbps (with 64QAM and 2x2 MIMO), virtually identical to 42.5 Mbps for LTE in a 5 MHz band channel.[26]

A key advantage that LTE offers over HSPA+ is a result of its ability to use larger channel bandwidths. This advantage disappears if only 5 MHz channels are available.

2.2.4 Sub-1 GHz frequencies have more attractive propagation characteristics, and consequently larger cell sizes

Radio waves are local disturbances in electromagnetic fields which propagate outwards from an antenna. The antenna could be sited on a base station or, at the user's end, inside a mobile device such as a phone, tablet or laptop. Different frequencies have different propagation characteristics, which determine:

- How far the radio wave travels
- The degree to which signals degrade as they travel, particularly around built up areas. Degradation can be caused by multipath effects such as diffraction, reflection and scattering; non-line of sight path loss, caused by reflections increasing the distance a signal travels; and absorption into materials through which the signal must travel.

The propagation characteristics of a frequency determine the range of a cell used for mobile communications. Lower frequency bands typically offer better propagation characteristics. Waves using these frequencies travel further and perform better when faced with obstacles. Hence operators can use larger cell sizes for each base station. Conversely, networks using the higher frequency bands have poorer propagation characteristics, and so require smaller cell sizes. Table 8 shows the ranges of cells using frequencies from 800 to 2600 MHz in three typical geotypes:

- Urban, assumed to be a built-up area with office buildings and apartments of four or more stories, densely concentrated
- Suburban - assumed to be residential housing with homes of two stories, more dispersed
- Rural - assumed to be open areas, with some housing, and coverage required in outdoor areas[27] .

Cell range km[28]	800 MHz	900 MHz	1800 MHz	2100 MHz	2600 MHz
Urban	0.95	0.87	0.39	0.34	0.29
Suburban	4.15	3.89	1.08	0.94	0.79

[26] [26] "LTE for UMTS", Holma & Toskala, Figure 13.11

[27] Motorways can be considered as an additional geotype but have been excluded as they represent a relatively small percentage of total traffic

[28] Three sectors per BTS, BTS height = 30m, mobile height = 2m

Cell range km[28]	800 MHz	900 MHz	1800 MHz	2100 MHz	2600 MHz
Rural	13.79	13.08	9.90	9.38	8.85

Table 8: Cell range for different frequencies in different geotypes

Source: PA Consulting analysis[29]

The cell range for sub-1GHz spectrum is similar in urban, suburban and rural geotypes, and declines significantly for supra-1GHz spectrum. This has an impact on the coverage area of each cell. The difference in cell coverage areas between sub- and supra-1GHz spectrum is pronounced:

- The coverage area of a cell in a rural area using supra-1GHz spectrum is between 50-60% less than the coverage area of a cell using sub-1GHz spectrum
- The coverage area of a cell in an urban or suburban area using supra-1GHz spectrum is between 83-96% less than the coverage area of a cell using sub-1GHz spectrum.

2.2.5 The cost implications are likely to have a greater impact in rural areas

This variation in cell ranges has a significant impact on the number of base stations required to provide coverage. Table 9 shows the differences relative to a network using 800 MHz spectrum of the number of base stations required to achieve coverage using the different frequencies.

Multiples vs 800 MHz	800 MHz	900 MHz	1800 MHz	2100 MHz	2600 MHz
Urban	X 1.0	x 1.2	x 5.9	X 7.9	X 10.9
Suburban	X 1.0	x 1.1	x 14.7	X 19.7	X 27.4
Rural	X 1.0	x 1.1	x 1.9	X 2.2	x 2.4

Table 9: Relative number of base stations required to achieve coverage at each band

Source: PA Consulting analysis[30]

The difference in the number of base stations required to provide coverage has a significant impact on the relative costs of rolling out networks using different frequencies. PA has assumed that the breakdown in cell sites by area type in the Netherlands is as follows:

- Urban: 35%

---

[29] Cell ranges calculated using:

- ETSI TR43.030 Appendix B.1, Hata model for 800 MHz and 900 MHz bands

- ETSI TR43.030 Appendix B.2, COST 231-Hata model for 1800 MHz, 2100 MHz and 2600 MHz bands

Note that the COST 231-Hata model is specified up to 2000 MHz, but has been used here as a close approximation for the 2.1GHz and 2.6GHz bands.

Building penetration loss assumptions:

- Urban: 20dB, Suburban: 10dB, Rural: 5dB

[30] These figures are normalised for comparison with the number of base stations required to achieve coverage at 800 MHz

- Suburban: 40%
- Rural: 25%.[31]

Using that split of base stations by area type, Table 10 shows the relative costs of rolling out a mobile network for each frequency.

Multiples vs 800 MHz	800 MHz	900 MHz	1800 MHz	2100 MHz	2600 MHz
Overall relative cost	X 1.0	X 1.2	x 8.4	X 11.18	x 15.4

Table 10: Relative costs of mobile networks of achieving national coverage in the Netherlands

Source: PA Consulting analysis[32]

Again, the cost of rolling out a network using sub-1GHz spectrum is broadly similar, with a 20% difference between the cost of rolling out a network using 800 MHz and the cost using 900 MHz. The cost of using supra-1GHz spectrum has a wider variation, with a network using 2600 MHz spectrum costing nearly twice that of a network using 1800 MHz spectrum. However the difference between sub and supra-1GHz spectrum is most pronounced, with the cost difference ranging between 8 and 15 times.

This range of costs is particularly important during a network operator's early years of operation when its coverage is limited. A mass market operator needs to reach equal levels of coverage with its peers in order to achieve equality of attractiveness and grow its subscriber base. For an operator with only supra-1GHz spectrum, this would require a significantly larger capital investment in network equipment than an operator with a mix of spectrum resources.

A conclusion of this analysis may be that sub-1 GHz spectrum offers a greater advantage to network operators in urban and suburban areas than in rural areas. However in practice the relative difference is greatest in rural areas:

- Most network operators will have access to both sub and supra-1 GHz spectrum. Operators will intend to use the additional capacity of supra-1 GHz spectrum to provide coverage in urban and suburban areas where users and traffic are concentrated
- A network operator would opt for a network architecture with supra-1 GHz base stations cell areas spaced to enable focus on traffic hotspots rather than providing coverage. Sub-1 GHz spectrum

[31] Studies for Ofcom in the UK indicate the split of base stations by geotype is approximately 30% urban, 35% suburban, 35% rural (by site numbers). We assume here that the Netherland has a greater proportion of urban and suburban compared to the UK.

[32] The proportion of total base stations allocated to three geotypes required to achieve national coverage in the Netherlands is assumed to be:

- Urban: 35%, Suburban - 40%, Rural: 25%

This assessment assumes the cost of achieving coverage is directly proportional to the number of base stations required to achieve coverage. There may be other factors such as the cost of providing backhaul that increase the cost of achieving coverage in one geotype relative to another, but this is not assumed to make a significant impact on the overall relative costs.

cells would be co-located with the supra-1 GHz cells where possible, and positioned to provide coverage outside of areas of greatest traffic

- Where required hotspots would be addressed with higher frequency spectrum.

The impact of the absence of sub-1 GHz spectrum on costs would therefore be most pronounced in rural areas, where population is less dense. However a network operator would not be able to use an optimal network architecture to achieve national coverage, and would therefore incur additional costs in suburban and urban areas as well.

2.2.6 At present operators are placing a premium on the sub-1 GHz bands

Benchmarking the prices paid for sub and supra-1 GHz spectrum in auctions around the world suggests that operators place a significant premium on lower bands over higher frequencies giving evidence of the value such frequencies bring to both incumbent and new entrant mobile businesses.

Analysis of the recent "big bang" auction of spectrum in Germany is a good indicator of the relative value of spectrum in different bands, undistorted by time or location. Operators paid seven times more for sub- rather than supra-1 GHz spectrum at this auction.

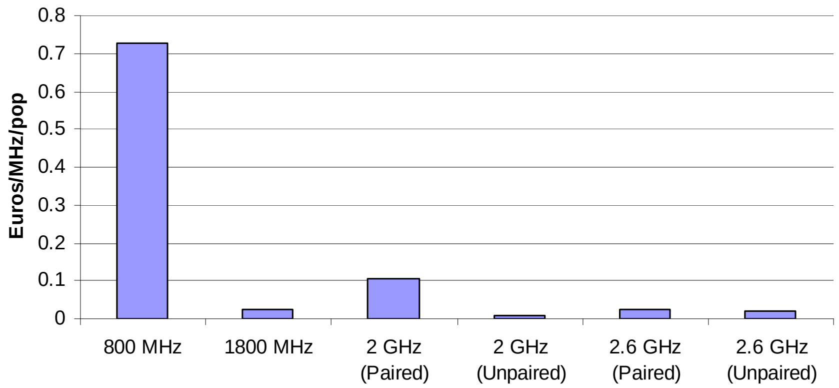


Figure 4 : Prices paid in German 2010 spectrum auction

Source: PA Consulting analysis[33]

The winning bidders for 800 MHz spectrum, T-Mobile, Vodafone and O2, paid almost 20 times per MHz compared with the value of 2600 MHz spectrum. This indicates that the properties of sub-1 GHz spectrum, enabling wide area coverage and in-building penetration are, at present, more highly valued than the properties of higher frequencies.

[33] Bundesnetzagentur http://www2.bundesnetzagentur.de/frequenzversteigerung2010/ergebnisse.html,

2.3 Requirement for sub-1 GHz spectrum

Question 3: Given the technological and market developments that can reasonably be expected during the next 5 to 10 years: Is it necessary for a mobile telecommunications service provider, with a nationwide mass-market ambition, and taking into account the common expectance of a return on investment by its shareholders, to have sub-1 GHz frequencies (800- and 900 MHz) at its disposal?

In today's market, access to sub-1 GHz spectrum may be essential to the success of a mobile telecommunications service provider with a nationwide mass-market ambition. Lack of access to sub-1 GHz spectrum will result in a material competitive disadvantage to a mobile operator with national mass market ambitions. As indicated in our response to Question 2 it is most unlikely to be cost effective to roll out a national network with supra-1GHz spectrum in contrast with operators that have access to sub-1GHz. This is one of the main reasons that new entrants operating at 2100 MHz today are typically compelled to enter into roaming agreements to achieve national coverage rather than embark on national build out programmes.

In the future, technical and market developments are in aggregate likely to increase the need for access to sub-1 GHz spectrum while also making access more feasible. The most noteworthy technical and market developments are:

- Significant increases in capacity requirements
- Spectrum refarming strategy decisions being taken by incumbents
- Network/spectrum/site sharing becoming increasingly common
- The opportunity to acquire new and additional sub-1GHz spectrum.

2.3.1 Capacity requirements will grow significantly but have limited bearing on a requirement for sub-1 GHz spectrum access

Markets around the world have experienced an increasing trend of traffic and revenue shifting from traditional voice to data services. The years since the turn of the Millennium have been characterised globally by the development and adoption of data services and the increased revenue contribution from these services. Operators, particularly in developed countries, have recently experienced rapid growth in data traffic driven primarily by the uptake of data dongles and the growing popularity of smart phones such as the iPhone.

As mentioned in response to Question 2, each block of sub-1 GHz spectrum offers the same capacity as the same sized block of supra-1 GHz spectrum. The implication of this is that an operator that is capacity constrained will not necessarily favour sub-1 GHz spectrum over supra-1 GHz spectrum. However, as larger contiguous blocks of spectrum offering greater capacity tend to be available at higher frequencies, a capacity constrained operator is more likely to favour higher spectrum bands. As areas of capacity peaks tend to be localised around areas of high population density, the poor coverage characteristics of supra-1 GHz spectrum are unlikely to be of major concern.

2.3.2 Spectrum refarming may magnify the disadvantage faced by an operator without sub-1 GHz spectrum

Until recently, spectrum holdings in the 900 MHz band were reserved for GSM services as specified in the GSM directive. Recent moves towards technology and service neutrality have opened up the 900 MHz band to alternative technologies.[34] Many operators are now starting to make use of this spectrum to deploy UMTS networks, in particular to support mobile broadband services.

Operators without sub-1 GHz spectrum face disadvantages from not having the option to refarm spectrum:

- Operators using supra-1 GHz spectrum, as highlighted in response to Question 2, face higher network rollout costs than operators refarming sub-1 GHz spectrum for mobile broadband. An incumbent operator with a range of spectrum allocations has the option to use refarming to optimise its network rollout costs by utilising some, or all, of its 900 MHz spectrum for LTE coverage. A new entrant, or existing operator without sub-1 GHz spectrum, only has the option to roll out LTE over higher spectrum bands, likely to be in the 2600 MHz band. Network rollout costs will consequently be far higher than those faced by incumbents.
- Incumbents have a potential time to market advantage by rolling out mobile broadband over an existing sub-1 GHz network topology rather than designing a new topology based solely on 2600 MHz. Incumbents with 900 MHz holdings will have an existing network planned around this spectrum band which, until any refarming decision, would have been used for 2G voice services. If this spectrum is refarmed for LTE, the operator would possibly be able to make use of the existing passive network infrastructure to roll out its new LTE network. This could provide a significant time to market advantage over an operator having to build a new network over 2600 MHz frequencies.

2.3.3 Network sharing will help all operators with national coverage of new technologies, but those with ownership of sub-1 GHz spectrum will benefit most

Network or spectrum sharing between operators is becoming increasingly common, often driven by the savings that can be achieved in deploying UMTS and LTE networks. Analysis suggests that savings of over 30% of Capex and ongoing Opex are available when the burden of rolling out a new network is shared[35]. This may provide new entrants with an attractive alternative to roaming as a means of achieving national coverage.

In Europe and around the world there have been many network sharing arrangements, as shown in Table 11, and there is a growing trend of further sharing agreements. At present there are no network-sharing agreements in place in the Netherlands, although this type of arrangement is not unknown, for example T-Mobile and Orange were sharing their UMTS networks prior to 2004. T-Mobile's acquisition of Orange resulted in the full consolidation of their two networks. Furthermore, spectrum sharing is not allowed under current licence terms unless a joint venture is formed. In the context of this trend it

[34] Council Directive 87/372/EEC ('the GSM Directive')

[35] PA analysis 2009

is not unreasonable to consider the possibility of the Dutch operators sharing their networks to help further manage costs.

Partners	Year	Geographical scope	Site sharing	2G RAN sharing	3G RAN sharing	4G RAN sharing	Spectrum sharing
Tele2 + TeliaSonera	2001	Sweden (full country)			✓		
Hi3G + Telenor	2001	Sweden (rural)			✓		
H3G + Telstra	2004	Australia			✓		
Vodafone + Optus	2004	Australia			✓		
Vodafone + Orange	2006	Spain (rural)			✓		
Tele2 + Network Norway	2007	Norway (metro coverage)		✓	✓		
H3G + T-Mobile	2007	UK	✓		✓		
Vodafone + Orange	2008	UK			✓		
Telefónica + Yoigo	2007	Spain	✓				
Orange + Yoigo	2008	Spain	✓				
Telefónica + Vodafone	2009	Germany, Ireland, Spain, UK, Czech	✓				
Tele2 + Telenor	2009	Sweden (full country)				✓	✓

Table 11 : Network/spectrum sharing partnerships sample

Source: PA Consulting analysis

For clarity, the different options for sharing agreements are defined below in Table 12.

Site sharing	Shared use of passive infrastructure including masts, towers and real estate. Maintenance costs for the sites are also shared.
RAN sharing	Shared use of electronic equipment, most commonly base stations.

Spectrum sharing	Shared use of combined, contiguous spectrum assets providing greater capacity and potential data rates.

Table 12 : Network/spectrum sharing options

In the case of a new entrant seeking to reduce its deployment costs, it may well aim to share its network with an existing operator. The options for network sharing typically range from full network sharing to site sharing only.

In the case of site sharing only, deployment of a network based on supra-1 GHz spectrum whilst utilising sites on an existing operator's grid that has been planned around an original 900 MHz deployment could result in significant holes in coverage. If a new entrant had access to sub-1GHz spectrum, this band could be used to deploy a network to ensure full coverage to all their customers, with the higher frequencies deployed in parallel to ensure capacity and throughput to the majority of their customers.

In the case of network sharing, a new entrant will not be able to enter into a network sharing deal in any areas that a partner wishes to make use of its 900 MHz spectrum. The partner would have little incentive to offer a sharing arrangement with a rival that had no ownership of 900 MHz spectrum. Furthermore, in cases where incumbents share with one another but not the new entrant, the new entrant will be significantly further disadvantaged.

While it can be seen that network sharing is a helpful development for new entrants to achieve national coverage, their options for sharing may be much more attractive if they have access to sub-1GHz spectrum.

2.3.4 Early access to sub-1GHz spectrum is most beneficial to a new entrant

Timing of access to sub-1GHz spectrum will be of importance to any new entrant. Being able to use this spectrum will be of greatest advantage to a new entrant in the early stages of their network deployment. In the early phases of operation, a new entrant is unlikely to be capacity constrained and will be prioritising cost efficient coverage. By 2017, a new operator with nationwide mass market ambitions that lacks sub-1 GHz spectrum will have had to address its nationwide coverage requirements through alternative coverage mechanisms such as national roaming. Alternatively, a new entrant may attempt to come to a network sharing agreement with an incumbent but, as discussed in Section 2.3.3, network sharing will be challenging without ownership of sub-1 GHz spectrum.

The two upcoming auctions present opportunities for a new entrant to acquire sub-1 GHz spectrum:

- Expiry of incumbent 900 MHz licences, possibly in 2013
- Spectrum in the 800 MHz band released as a result of the digital dividend, possibly in 2017.

The prospect of a new entrant acquiring sub-1GHz spectrum is different for each auction event.

Licences for spectrum in the 900 MHz band are due to expire in 2013 and are expected be re-auctioned. When evaluating its maximum bid for the auction, a bidder will consider the total cost of ownership for the network as well as the revenues it will generate from its prospective customer base.

- Incumbents that currently occupy the 900 MHz spectrum have already invested in assets to meet its national coverage and capacity requirements and already have a substantial customer base. This is a significant advantage compared to a new entrant who would have to incur the costs of building an equivalent network and acquiring an equivalent customer base over a period. As a result, the incumbents can be expected to be in a much stronger position to reacquire this spectrum.
- In this context, bringing the 800 MHz auction forward may present a new entrant with an important opportunity to acquire sub-1 GHz spectrum. A new entrant is still likely, however, to have to win a licence in a competitive auction in which existing operators are motivated to block new entrants to the market.
- Furthermore, a simultaneous auction of the 800 MHz and 900 MHz bands may present an advantage over two auctions separated over a period of time. This is because an incumbent operator can be expected to be more likely to relinquish a portion of its 900 MHz holding if it is certain it will be able to acquire spectrum in the 800 MHz band. A lack of certainty over being able to secure spectrum in the 800 MHz band, caused by separate auctions, can be expected to encourage incumbents to maximise their holding of spectrum in the 900 MHz band. A simultaneous auction would present all participants with greater options to acquire spectrum. At the time of the auction, the spectrum in the 800 MHz band need only have guarantees of its future availability, rather than actually be available for immediate use.

Mature operators that have rolled out and operated networks based solely on supra-1 GHz spectrum for a number of years, such as O2 and E-Plus in Germany, have been noted to show a keen interest in sub-1 GHz spectrum. Both German operators bid in the recent 800 MHz auction, although only O2 was successful in securing this spectrum. Their interest is due to the step change in technology and services currently sweeping across the telecoms market. The combination of the move to LTE and the surge in demand for mobile broadband is set to force major operators into another significant, nationwide network rollout. The interest shown in the 800 MHz auction by mature operators that have not previously owned sub-1 GHz spectrum is as a result of the desire to minimise the rollout costs for this forthcoming period of network development. This suggests that in the Netherlands, while early access to sub-1GHz spectrum is most favourable, access to this spectrum even to a maturing new entrant will still be helpful.

2.4 Treatment of sub-1GHz frequencies

Question 4: Given the answers to the foregoing questions, is there, taking into account the Dutch government's tentative objective to facilitate a fourth mobile network operator, sufficient reason to treat sub-1 GHz frequencies differently from higher frequencies?

There is sufficient reason to treat sub-1 GHz frequencies differently from higher frequencies to support the tentative objective of facilitating a fourth mobile network operator. New entrants with nationwide, mass market ambitions face considerable disadvantages in their attempts to disrupt the market and compete successfully with the incumbents. The reasons are numerous but a lack of sub-1 GHz spectrum is one variable over which governments can exert control. There are many examples of regulators recognising that imbalances in spectrum holdings are an issue for new entrants and therefore have taken steps to treat sub- and supra-1 GHz spectrum differently.

2.4.1 New entrants face considerable disadvantages when entering mature markets

New mass market operators start with significant disadvantages to incumbents. Table 13 highlights how difficult it is for a new entrant when entering a maturing or mature market to overcome its position as the smallest operator. In all cases, the new entrant remains the smallest, and in some cases by a significant margin even after an extended period. The examples of Bouygues Telecom in France and O2 in Germany are of particular note as they demonstrate that, even after a significant period of time, a new entrant can still lag notably behind the rest of the market.

Operator	Country	Years since launch	Total MNOs	Market share for equivalence	Actual market share as of March 2010	Market position
H3G	UK	7	5	20%	7.2%	5
O2	Germany	12	4	25%	14.7%	4
Bouygues	France	14	3	33%	18.5%	3
H3G	Italy	7	4	25%	10.2%	4
H3G	Denmark	7	4	25%	7.1%	4
Yoigo	Spain	4	4	25%	3.1%	4
H3G	Ireland	5	4	25%	9.2%	4

Table 13 : Market share of new entrants to mature markets

Source: PA Consulting analysis

The reasons for this are varied, but include:

- The state of the market, with penetration of over 100%, meaning the new entrant cannot rely on market growth to develop its subscriber base as its competitors may have done
- Previous significant network investment from incumbents
- The lingering impact of the network effect, despite regulators' attempts to reduce termination charges and operators' network-independent tariff bundles
- Brand power exerted by established incumbents

- The high levels of focus placed on customer retention by all operators in mature markets
- Perceived or actual inferior coverage offered by a new entrant.

Lack of access to sub-1 GHz spectrum is however an important component of this disadvantage. Having access to only supra-1 GHz frequencies increases the cost and complexity of the rollout of network infrastructure required to provide a national service. This delay can damage perceptions of the service, and the additional capital requirement can adversely affect the financial position of the operator.

2.4.2 There are ways of reducing network rollout costs but ownership of sub-1GHz is most favourable outcome for a new entrant

New entrants appear to have two opportunities to mitigate the impact of a lack of access to sub-1 GHz spectrum:

- National roaming
- Network sharing.

Neither of these approaches is likely to bring the full range of benefits associated with a new entrant securing its own spectrum allocation and rolling out infrastructure. National roaming could limit a new entrant's ability to differentiate itself on its network coverage and services as well as limit the profit it might make from reselling this infrastructure. Network sharing is unlikely to be a viable option unless some 1 GHz spectrum is secured. This section explores these two options in further detail.

National roaming could limit network based competition

Enforced national roaming is a mechanism commonly used by regulators around the world to facilitate the entry of a new operator. A new entrant is then free to focus on building a network in areas of greatest commercial opportunity. For example, as one of the operators deemed to have significant market power in the Norwegian market, Telenor is obliged to provide national roaming services. The prices they can charge are controlled by the regulator and calculated under a "retail minus" model.[36]

Instances of operators having to make use of national roaming agreements when they do not own sub-1 GHz spectrum are common around the world. Table 14 shows examples of operators without sub-1 GHz spectrum making use of national roaming agreements.

Country	Operator	Spectrum holding	Launch date	National roaming approach
UK	3	2100 MHz	2003	National roaming with Orange
Germany	O2	1800 MHz, 2100 MHz	1998	Recently (2009) ended roaming agreement with T-Mobile. Now owns 800 MHz spectrum
Spain	Yoigo	2100 MHz	2006	National roaming with Movistar

[36] http://www.telenor.com/en/investor-relations/company-facts/business-description/telenor-norway

Country	Operator	Spectrum holding	Launch date	National roaming approach
3	Italy	2100 MHz	2003	National roaming with TIM
3	Austria	2100 MHz	2003	National roaming with Mobilkom Austria
Sweden	3	2100 MHz	2002	National roaming with Vodafone
Ireland	3	2100 MHz	2005	National roaming with Vodafone

Table 14 : National coverage strategy for operators without sub-1 GHz spectrum

Source: PA Consulting analysis

Operators use roaming agreements to cover areas of low population density that are uneconomical to comprehensively cover with a network based on supra-1 GHz spectrum. These agreements, however, have the drawback of limiting network-based competition. The roaming party will be limited to offering identical coverage and performance to the network owner as well as possibly being restricted to offering services enabled by that network. Some element of profit margin is likely to be extracted by the network owner; any increase in this margin extraction will further decrease that available to the roaming party.

Network sharing is unlikely to be viable without some sub-1 GHz spectrum holding

Two operators with similar spectrum assets may be able to share a network or spectrum in order to reduce the cost of rolling out a network. This would require operators to combine network, and possibly spectrum, assets and so reduce the disadvantage of higher network capital and operating costs.

As discussed in the answer to Question 3, network sharing is unlikely to be a viable option unless the operators own similar spectrum. Without similar spectrum bands, the two operators require different network topologies designed around different cell ranges. Therefore, if a new entrant does not have sub-1 GHz spectrum it is not an attractive partner for an operator with sub-1 GHz spectrum. Where that is the case the new entrant will be unable to enter a network sharing agreement in the most advantageous areas, and the relative advantage of incumbents may be enhanced as they enter into sharing agreements with each other.

2.4.3 Regulators are intervening in the allocation of sub-1 GHz frequencies to promote equalisation of spectrum holdings

It is evident that mass market new entrants face a hard task to develop a strong competitive position and have an impact on the market. One of the reasons for this is the disadvantage felt by many new entrants of having spectrum only in the supra-1 GHz bands. This means that the new entrant incurs higher network capital and operating expenditure as a result of the greater number of base stations required to cover the country. There may be ways to mitigate this disadvantage, but:

- National roaming does not meet the requirement to enhance competition

- Network and spectrum sharing at sub-1 GHz frequencies is unlikely unless a new entrant has an attractive asset to contribute.

Regulators are taking action to support new entrant's attempts to redress the imbalance of sub-1 GHz spectrum ownership. To do this, regulators take advantage of opportunities offered by:

- Newly available spectrum such as E-GSM or digital dividend bands
- The introduction of service and technology neutrality
- The expiry of sub-1 GHz spectrum licences.

Regulators have reserved blocks of new spectrum allocations for new or late entrants

The release of the E-GSM band, which had been reserved for other users such as the military, offers an example of how regulators have attempted to redress imbalances in spectrum ownership among mobile network operators. Regulators have either reserved the newly available 900 MHz spectrum for new entrants, or required new entrants to exchange higher frequency for lower frequency spectrum.

In Germany for example, the E-GSM band came available in 2005. The German regulator, the Bundesnetzagentur, assigned 2 x 5 MHz ranges from this band to both O2 and E-Plus, neither of which had access to 900 MHz spectrum. E-Plus and O2 were required to return some 1800 MHz spectrum which was subsequently provided to T-Mobile and Vodafone. The Bundesnetzagentur believed that the lower frequency spectrum provided a significant benefit to the two smaller operators and enabled a greater level of competition, stating that "This spectrum in the range 900 MHz is of extreme importance especially for GSM network expansion in rural regions"[37].

The introduction of technology neutrality enables regulators to reallocate spectrum

The EU recently amended its directive concerning the reservation of the 900 MHz band for GSM (Council Directive 87/372/EEC) to allow UMTS and LTE technology to be deployed in the 900 MHz band. As discussed in section 2.3.2, regulators around Europe are concerned that enabling incumbents to use their 900 MHz spectrum for mobile broadband will give incumbents an advantage over operators without sub-1 GHz spectrum.

In order to mitigate this concern, Ofcom, the UK regulator, is proposing to offer incumbents the opportunity presented by technology neutrality in exchange for returning a portion of their 900 MHz spectrum. As part of its refarming strategy, Ofcom has proposed requiring Vodafone and O2, the holders of sub-1 GHz spectrum, to give up a portion of their spectrum allocations. The released spectrum, suggested as being 2 x 5 MHz, would then be auctioned to another operator with Vodafone and O2 restricted from bidding. This would "allow a third operator to have access to this particularly important spectrum"[38]. Ofcom has stated that holding 900 MHz spectrum represents a competitive advantage for the holders over those without this spectrum, and that there is a risk that an operator

---

[37] http://www.bundesnetzagentur.de/cln_1911/SharedDocs/Pressemitteilungen/EN/2005/050415FrequenciesMobileComms.html?nn=148882

[38] http://stakeholders.ofcom.org.uk/consultations/spectrumlib/summary

without 900 MHz spectrum may decide not to roll out 3G services. This would reduce the level of competition in the market.[39] Ofcom also considered redistribution of spectrum held in the 1800 MHz band although the conclusion was that redistributing spectrum in this band would not promote additional competition.

Licence expiry offers regulators the opportunity to redistribute of spectrum

In many countries in Europe 900 MHz spectrum licences that were distributed between 1990 and 2000 had licence periods of 15 -20 years. As these licences expire, regulators have to decide whether these licences will be renewed, extended or re-auctioned. Renewal and extension of the 900 MHz licences extends any advantages of the incumbents over operators arising from their lack of sub-1 GHz spectrum. Re-auctioning the licences may fail to enable redistribution of spectrum as holders of 900 MHz have a financial advantage as a result of their sunk network investment. The incumbent may therefore be able to outbid a new entrant, and maintain the status quo. Regulators therefore may decide to intervene in the reallocation process to ensure that spectrum resources are equalised.

In Sweden, the four incumbent operators had lobbied the PTS, The Swedish regulator, to extend their 900 MHz licences, which had been due to expire at the end of 2010, to 2025. The PTS extended these licences and changed the conditions to service and technology neutrality, allowing the rollout of UMTS and LTE technology in a band that had previously been reserved for GSM. The PTS also required that spectrum is reallocated in such a way that new entrant Hi3G, previously limited to 2100 MHz spectrum, gained 2 x 5 MHz in the 900 MHz band. The regulator has justified this by recognising that technology neutrality creates "competitive advantages…for existing operators in the band, mainly in relation to UMTS operators that do not have access to 900 MHz frequencies"[40]. As illustrated in the answer to Question 2, rolling out mobile communications services in the 900 MHz band is considerably less expensive than in the 2100 MHz band. The partial transfer of certain frequency space is thus a precondition for dealing with the risk that competition between UMTS operators may become distorted.

2.4.4 There may be alternative approaches to a cap to ensure a new entrant has access to sub-1 GHz spectrum

A spectrum cap on incumbents may not be the only approach to ensuring that a new entrant has access to sub-1 GHz spectrum. Regulators have the option to reserve spectrum for a new entrant, for example in order to help equalise spectrum holdings with incumbents. The examples of the E-GSM band in Germany and approach of the PTS to refarming 900 MHz spectrum are both instructive, with the regulator promoting the interests of new entrants by reserving spectrum.

Another measure regulators can adopt is to design an auction format that greatly increases the prospect of a new entrant gaining access to new spectrum. The example of the Polish regulator's approach to the allocation of 2600 MHz spectrum may be instructive. UKE has proposed a format for the 2600 MHz spectrum auction that greatly encourages the four Polish operators into spectrum (and

---

[39] http://stakeholders.ofcom.org.uk/binaries/consultations/liberalisation/summary/liberalisation.pdf

[40] http://www.pts.se/upload/Beslut/Radio/2009/08-12019-decision-900-mhz-march-2009.pdf

network) sharing strategies by making the spectrum available in two equal sized lots of paired 2 x 35 MHz allocations. The scarcity of spectrum that this format creates presents operators with the likely prospect of a bidding war if attempting to secure the spectrum alone. Then, if successful, the operators will acquire an allocation that cannot be used efficiently by a lone operator. As LTE networks have a maximum bandwidth of 20 MHz, such an allocation of 2 x 35MHz cannot be used efficiently by one operator..

If the four Polish operators form two pairs of network sharing partnerships, the prospect of a damaging bidding war is greatly diminished. Furthermore, a competing bid from a consortium of two operators with the intention of rolling out a shared network would be capable of making better use of the available spectrum. These two sharing operators would therefore be in a much stronger position in the auction and therefore more likely to win. This approach therefore encourages spectrum and network sharing discussions. In a market with three incumbent operators and one prospective new entrant, one of the incumbent operators might be incentivised to pair-up with a prospective new entrant. A drawback of this approach is that network infrastructure based competition may be reduced because operators are offering their services over a common infrastructure.

Whether offering spectrum in only 2 lots of 2x 15 MHz would be a sufficient incentive alone to promote sharing with a prospective new entrant is uncertain, although further suitably designed auction conditions might make this more likely.

Any measure, such as spectrum capping, spectrum reservation or auction design, intended to provide a new entrant with access to the 900 MHz band is likely to be met with challenges from the incumbent operators. Such a policy would force at least one of them to vacate some, or all, of their current 900 MHz holding. This might not support an objective of enabling business and service continuity and may not be in the best interests of the wider market. Such concerns would not apply to the 800 MHz band.

2.5 Size of the cap on sub-1GHz frequencies

Question 5: If your answer to question 4 is positive, then, seen in the light of your answer to question 3, is a cap of 2x20 MHz on sub-1 GHz frequencies proportionate to ensure the entrance of a fourth mobile network operator without hampering the incumbent mobile network operators too much?

A spectrum cap applying to the incumbents' ability to acquire spectrum will certainly support the entrance of a fourth operator if there is demand from investors to fund a new entrant. The proposed cap of 20 MHz will not restrict incumbent operators although there is a risk this may limit a new entrant's ability to compete effectively, depending on the outcome of the auction. Alternatives to a spectrum cap are available if the Ministry wishes to mitigate this risk.

Incumbent operators are in a strong position to reacquire their spectrum allocations in the 900 MHz band. This strength arises from the first mover advantage of having already invested in assets to meet national coverage and capacity requirements and already having a substantial customer base. These advantages are also applicable, albeit to a lesser extent, to spectrum in the 800 MHz band. As a result, incumbent operators are well placed to take up their full allocation of 2 x 20 MHz and a new entrant might be left with only 2 x 5 MHz. In this instance, in areas where a sub-1 GHz spectrum network provides the only coverage, a new entrant may be limited in it service offerings.

2.5.1 A cap of 20 MHz should not unduly restrict incumbents

A cap of 2 x 20 MHz should not unduly restrict incumbents in terms of their planning, operations or service offerings. LTE is likely to be the default technology for operators to deliver data services in the near future. One of the key reasons for migrating to LTE is its ability to support higher channel bandwidths of up to 20 MHz. This would deliver higher data rates to users and a “truer” mobile broadband experience. LTE is only specified up to a 20 MHz channel bandwidth and equipment being designed and manufactured to support LTE services supports blocks of up to 20 MHz. This may change, but at present incumbents will not be able to make use of more than 2 x 20 MHz of contiguous spectrum to which the proposed cap limits them.

In practice, because of the auction strategy, it will be challenging for any operator to secure 20 MHz of contiguous spectrum. This will result in spectrum allocations split into blocks of less than 2 x 20 MHz for some or all of the incumbents.

The total sub-1 GHz spectrum allocation that MEZA is considering auctioning is spilt across the 800 MHz and 900 MHz bands in two blocks of 2 x 30 MHz and 2 x 35 MHz with these bands planned to be auctioned at different times. This implies that a maximum of two contiguous 2 x 20 MHz blocks are available from the combined total of 130 MHz. Further, depending on the auction rules, and the behaviour of the operators, it is possible that none of the incumbents may be able to secure 2 x 20 MHz of even 2 x 15 MHz of contiguous spectrum.

A contiguous allocation of 2 x 10 MHz or greater is sufficient to offer wideband services with a bandwidth advantage over HSPA+ which is limited to 5 MHz channel bandwidths[41]. In order to enable continuity of GSM services, incumbents will need to deploy some, or all, spectrum secured in the 900 MHz band to this end. As such, it is likely that an incumbent will only have 2 x 10 MHz or 2 x 15 MHz of contiguous spectrum available for LTE deployment as part of their 2 x 20 MHz cap, assuming auction lots permit this outcome. So long as the incumbents bid for at least this level of spectrum capacity then they will benefit from deploying LTE in this spectrum range.

Enabling continuity of GSM services will require reservation of sufficient spectrum to meet capacity demand. This demand is set to diminish over time as traffic migrates from GSM networks to UTMS and LTE networks. This migration is largely driven by three factors:

- Growth in mobile data consumption and the consequent adoption of smartphones suited to UMTS and LTE

[41] ETSI Technical Specification TS25.308 (3GPP release 9) will enable dual-cell HSDPA operation, aggregating two 5MHz channels to double throughput. However, this will come in conjunction with MIMO operation requiring large-scale cell-site hardware upgrade. Operators are likely to wait for LTE before committing to this considerable expense rendering this development largely obsolete.

- Operators driving traffic onto UMTS and LTE networks, commonly through handset discount policies
- Engineering choices forcing handsets to select networks based on other spectrum bands such as 1800 MHz where available.

Incumbent operators therefore have the means to influence the pace of traffic migration away from their GSM network. Through refarming spectrum at 900 MHz they can progressively use more of their sub 1 GHz allocation for LTE. Their entire sub 1 GHz allocation could therefore eventually be made available for LTE deployment should the operators consider this to be the best use of their spectrum assets.

An incumbent is also unlikely to require more than 20 MHz of spectrum to satisfy capacity constraints based on current reasonable expectations of growth in network traffic. Incumbents in the Netherlands already have a range of supra-1 GHz spectrum allocations with network assets appropriately deployed. Networks based on spectrum allocations in the 1800 MHz, 2100 MHz and 2600 MHz bands will have been deployed in areas of highest capacity demand. All of these bands are suitable for deployment of LTE.

2.5.2 The proposed spectrum cap may limit a new entrant's ability to compete with incumbents effectively

As discussed in section 2.3.4, incumbent operators are in a strong position to reacquire their spectrum allocations in the 900 MHz band. These advantages are also applicable, albeit to a lesser extent, to spectrum in the 800 MHz band. As a result, incumbent operators are well placed to be able to take up their full allocation of 2 x 20 MHz which would limit a new entrant to only 2 x 5 MHz. If this circumstance were to arise, the new entrant may be at a relative disadvantage in areas where a sub-1 GHz network provides their only coverage.

A new entrant deploying LTE over 2 x 5 MHz spectrum blocks will not able to offer a significant improvement over an incumbent's 3G service. 3G deployed using HSDPA and HSPA+ technologies are capable of delivering similar capacity and data rates from a 5 MHz channel. In contrast, a deployment of LTE with 2 x 20 MHz of spectrum offers data rates and capacity almost four times greater. The performance difference between a 5 MHz channel and a 20 MHz channel is illustrated below in Table 15.

Parameter	5MHz channel	20MHz channel
Peak data rate[42]	36.7Mbit/s	149.8Mbit/s
Average spectral efficiency[43] / Average network capacity	~1.7bit/s/Hz 8.5 Mbits / sector	~1.7bit/s/Hz 34 Mbits / sector

[42] "LTE for UMTS", Holma & Toskala, Table 9.3 for 64QAM with 2x2 MIMO

Parameter	5MHz channel	20MHz channel
Average edge-of-cell spectral efficiency[44] / average edge-of-cell data rate	~0.07bit/s/Hz 0.35 Mbit/s	~0.07bit/s/Hz 1.4 Mbit/s

Table 15: Peak and average data rates for 5 and 20 MHz channels for LTE

Source: "“LTE for UMTS”, Holma & Toskala, Table 9.3

If an incumbent were able to secure a contiguous block of 2 x 20 MHz, a new entrant with only 2 x 5 MHz would be at a competitive disadvantage in areas supported by the sub-1 GHz spectrum only. The new entrant may not be able to offer the higher quality data or video services that an incumbent could be able to offer. This may place the new entrant at a disadvantage to the incumbents, but only in areas where the new entrant did not have network infrastructure using supra-1 GHz infrastructure, i.e. in rural areas.

A more likely scenario is that any 2 x 20 MHz allocation of spectrum secured by incumbents would not be contiguous as it would be split between the 800 MHz and 900 MHz bands. In this instance, the largest contiguous block likely to be secured by an incumbent is 2 x 15 MHz. As such, any potential competitive disadvantage faced by a new entrant would be reduced, but would still be expected to be significant.

A new entrant with sub-1 GHz spectrum is most likely to use this band for deploying its network in areas requiring good propagation characteristics such as city centres with high building density and rural areas to help achieve national coverage. In the case where that operator also has spectrum in higher bands, in the 2600 MHz band for example, city centres are also likely to have complementary coverage supported by supra-1 GHz spectrum. It can be envisaged that the new entrant will be relying on the sub-1 GHz spectrum as it sole means of delivering services in rural areas. The new entrant may have to concede the market for national high speed mobile broadband, and wideband services to the incumbents in these areas. This may adversely affect the prospects of the new entrant, and it may also mean that the Government's tentative intention of encouraging a fourth national competitor is not met.

While this highlights a risk to the viability of the new entrant, there is no certainty that this is the case:

- The disadvantage posed by the differential to the incumbent's service offering, in areas supported by sub-1 GHz spectrum only, may not be sufficient to block the new entrant from providing some level of competition to the incumbents
- The new entrant with access to supra-1 GHz spectrum will use this spectrum to address urban and suburban areas and enable it to offer equivalent services to possibly the majority of users

[43] “LTE for UMTS”, Holma & Toskala, Figure 9.12 for macro case 1, 2x2 MIMO

[44] “LTE for UMTS”, Holma & Toskala, Figure 9.12 for macro case 1, 2x2 MIMO

- The new entrant would be able to secure 2 x 5 MHz which it may be able to use as a contribution to a network or spectrum sharing agreement with another operator, thereby ensuring it has access to the spectrum required to offer competitive services everywhere
- It is of course far from certain that a new entrant will receive only 2 x 5 MHz of spectrum. The new entrant may be able to secure more than 2 x 5 MHz depending on the intentions of the other bidders.

2.5.3 Alternatives are available that will remove the risk of a new entrant being unable to compete with incumbents

There are alternative options that the government may decide to pursue if it considers that the risk of market failure of a new entrant with only 2 x 5 MHz of sub-1 GHz spectrum is sufficient that it will prevent it from achieving its tentative objective of introducing a fourth operator. These alternative options include:

- An amount of spectrum greater than 2 x 5 MHz could be reserved for the new entrant. This would provide the new entrant with a guaranteed spectrum allocation of, for example, 2 x 10 MHz of spectrum.
- An auction process could be introduced which might lead to a new entrant and an incumbent partnering to purchase one of two blocks of sub-1 GHz spectrum. The new entrant would then most likely have access to 2 x 10 MHz or more of spectrum.
- The amount of spectrum the incumbents could be allowed to bid for could be reduced. For example, a cap of 15 MHz could leave the new entrant with 2 x 20 MHz of spectrum. This option would however create material drawbacks for the incumbents. If incumbent operators were to reacquire their entire previous holding in the 900 MHz band, it is likely they would use this for GSM service continuity in the first instance. Incumbents could therefore be left with a maximum of 2 x 10 MHz of contiguous spectrum for LTE deployment. This would limit data rates available to their customers in areas supported by sub 1 GHz spectrum only and ,as outlined in section 2.2.3, reduce their ability to support certain services and foster service innovation. Furthermore, the complexity of spectrum refarming would be increased for incumbents as would the cost of achieving this without disrupting end-user services.

While there is an evident risk for the success of a new entrant it is by no means certain that the current plan for a spectrum cap will result in a failure to meet the government's aims.

Appendix A: About PA Consulting Group

PA Consulting Group is a leading management, systems and technology consulting firm, operating worldwide in more than 35 countries.

We put together teams from many disciplines and backgrounds to tackle the most complex problems facing our clients, working with leaders and their staff to turn around organisations in the private and public sectors. Clients call on us when they want:

An **innovative** solution: counter-intuitive thinking and groundbreaking solutions

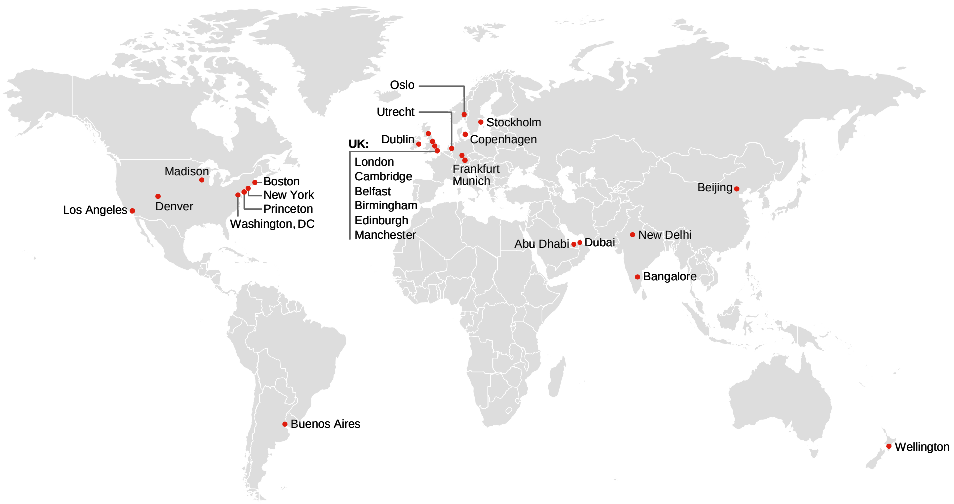
A highly **responsive** approach: we listen, and then we act decisively and quickly

Delivery of hard results: we get the job done, often trouble-shooting where previous initiatives have failed.

We are an independent, employee-owned, global firm of 3,000 talented individuals, operating from offices across the world, in Europe, North America, Middle East, Latin America, Asia and Oceania. We have won numerous awards for delivering complex and highly innovative assignments, run one of the most successful venture programmes in our industry, have technology development capability that few firms can match, deep expertise across key industries and government, and a unique breadth of skills from strategy to IT to HR to applied technology.

This evaluation was undertaken by staff from PA's telecommunications group, who work regularly with well-known telecommunications operators, regulators and vendors worldwide. PA has undertaken a large number of assignments for operators and regulators relating to mobile spectrum allocation, traffic modelling and licence bidding and award. Our technology experts have designed base stations, handsets and other equipment for many clients and have in-depth knowledge of mobile communications systems and mobile network dimensioning and planning.

PA offices worldwide



At PA Consulting Group, we **transform** the performance of organisations.

We put together teams from many disciplines and backgrounds to tackle the most complex problems facing our clients, working with leaders and their staff to turn around organisations in the private and public sectors. Clients call on us when they want:

an **innovative** solution: counter-intuitive thinking and groundbreaking solutions

a highly **responsive** approach: we listen, and then we act decisively and quickly

delivery of hard results: we get the job done, often trouble-shooting where previous initiatives have failed.

We are an independent, employee-owned, global firm of 2,700 talented individuals, operating from offices across the world, in Europe, North America, Middle East, Latin America, Asia and Oceania. We have won numerous awards for delivering complex and highly innovative assignments, run one of the most successful venture programmes in our industry, have technology development capability that few firms can match, deep expertise across key industries and government, and a unique breadth of skills from strategy to IT to HR to applied technology.

• defence • energy • financial services • government and public services
• international development • life sciences and healthcare • manufacturing
• postal services • retail • telecommunications • transportation

---

• strategic management • innovation and technology • IT • operational improvement
• human resources • complex programme delivery

Delivering business transformation

Corporate headquarters
123 Buckingham Palace Road
London SW1W 9SR
United Kingdom
Tel: +44 20 7730 9000
Fax: +44 20 7333 5050
E-mail: info@paconsulting.com

www.paconsulting.com