A STUDY OF DUTCH SPECTRUM HOLDINGS IN THE 2100 MHZ BAND

A report for the Ministerie van Economische Zaken

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FOREWORD

The Ministerie van Economische Zaken (MEZ) is considering extending the current Dutch 2100MHz spectrum licences for a period of a further 4 years, 2017 – 2021.

A specific feature of the current allocation of the 2100MHz band is that all licensed blocks do not comprise an exact multiple of 5MHz.

MEZ has approached PA Consulting to offer opinion on the effect of the variance in spectrum allocations in the 2100 MHz band, both currently and in the future period 2017 to 2021.

In engaging PA, MEZ has posed specific questions on the topic as follows.

1. Does the present allocation of the 2100 MHz licenses lead to significant unequal usage possibilities for the license holders for the period 2017 – 2021?
2. Is the answer to question 1 different, if expanding the licensed 2100 MHz band to 60.0 MHz as a starting point, in order to facilitate a possible subsequent swap?
   - This would mean the extension of one of Vodafone's licensed allocations to 14.9 MHz (instead of 14.6 MHz) and commensurate extension of one of T-Mobile's licenses to 10.3 MHz (instead of 10.0 MHz).
3. If the answer to question 1 is affirmative, to what extent do different usage possibilities lead to different values, where value is expressed as percentage difference between the total value of separate, non-adjacent licenses and the value of adjacent licenses?
4. Taking a modern network as a starting point, what are the approximate costs of making the 2100MHz licences contiguous?

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1 DOES THE PRESENT 2100MHZ ALLOCATION LEAD TO SIGNIFICANTLY UNEQUAL USAGE POSSIBILITIES FOR THE PERIOD 2017 – 2021?

Addressing the question of whether significant unequal usage possibilities may arise, it is necessary to break down the question into components for consideration. At the time of initial licensing, 2100 MHz spectrum was intended for the deployment of UMTS (3G) service. All three Dutch Mobile Network Operators (MNOs) deliver UMTS service at this band.

Subsequently, the EU introduced legislation mandating that spectrum is offered on a technology agnostic basis and can therefore be repurposed to support any of the cellular service standards. The 2100 MHz spectrum can therefore be refarmed and used by the MNOs to deliver LTE service.

Relevant consideration of potential unequal usage therefore must take in the delivery of;

- Continued UMTS service
- LTE service
- Delivery of both UMTS and LTE at 2100 during a transition period
- UMTS and LTE technology evolutions, namely dual-carrier (aka dual cell) HSPA and LTE-A carrier-aggregation
- Potential future technology evolutions affecting the period to 2021 under review.

Underpinning the conclusions summarised below, each of these themes above is addressed in turn in the subsequent sections of this chapter.

The conclusions from this chapter are as follows;

- The spectrum allocations do not confer advantage for delivery of UMTS service
- The spectrum allocations do not confer advantage for delivery of LTE service
- The spectrum allocations do not confer advantage during transition from UMTS to LTE
- Recommendations contained in the CEPT report do not alter interpretation of the 3GPP standards
- Evolutions of the UMTS and LTE standards do not afford any operator material advantage
- The spread of spectrum allocations does not confer advantage
- It is unlikely that the period 2017 – 2020 will see changes that alter existing conclusions.

1.1 The spectrum allocations do not confer advantage for delivery of UMTS service

Current 2100 MHz band spectrum allocations are depicted in the figure below, including the specific frequency ranges.

Figure 1: Current allocation of Dutch 2100 MHz spectrum

	Block 1		Block 2		Block 3		Block 4		Block 5		Block 6	
Operator	Vodafone		KPN		T-Mobile		KPN		Vodafone		T-Mobile	
Uplink	1920.3	1934.9	1934.9	1949.7	1949.7	1959.7	1959.7	1964.7	1964.7	1969.7	1969.7	1979.7
Downlink	2110.3	2124.9	2124.9	2139.7	2139.7	2149.7	2149.7	2154.7	2154.7	2159.7	2159.7	2169.7
Total bandwidth	14.6		14.8		10		5		5		10	
Nominal bandwidth	15		15		10		5		5		10	

Each of the six (paired) allocation blocks within the 2100 MHz band is an integer multiple of 5 MHz, except for the larger blocks allocated to Vodafone and KPN. These blocks are sized at slightly less than 15 MHz each – 14.6 MHz and 14.8 MHz respectively.

Lotting of the Dutch 2100 MHz spectrum was at the time intended for use to support delivery of 3G service, which gave rise to the selection of 5 MHz multiples. Nominally, a 5 MHz allocation is expected to and will support a single 3G carrier. A 15 MHz block will therefore support three 3G carriers.

In practice, a 3G carrier occupies less than the full 5 MHz block. The 3GPP standard states, "The nominal channel spacing is 5 MHz, but this can be adjusted to optimise performance in a particular deployment scenario".[1] The actual bandwidth requires for a carrier in practice is termed the 'occupied bandwidth. The UMTS occupied bandwidth is approximately 4.7 MHz per carrier.[2] In reality therefore, a spectrum allocation of less than the nominal 5 MHz can accommodate a single UMTS carrier.

Where an MNO seeks to accommodate a number of UMTS carriers of 4.7 MHz occupied bandwidth into a smaller-than-nominal 15 MHz allocation, individual carrier may need to be shifted closer together. The act of shifting them closer together allows for a smaller total required bandwidth. Such a facility for moving 3G carriers exists in increments of 0.2 MHz within the 3GPP standard.[3] This feature allows 3G carriers to be successfully shifted closer together.

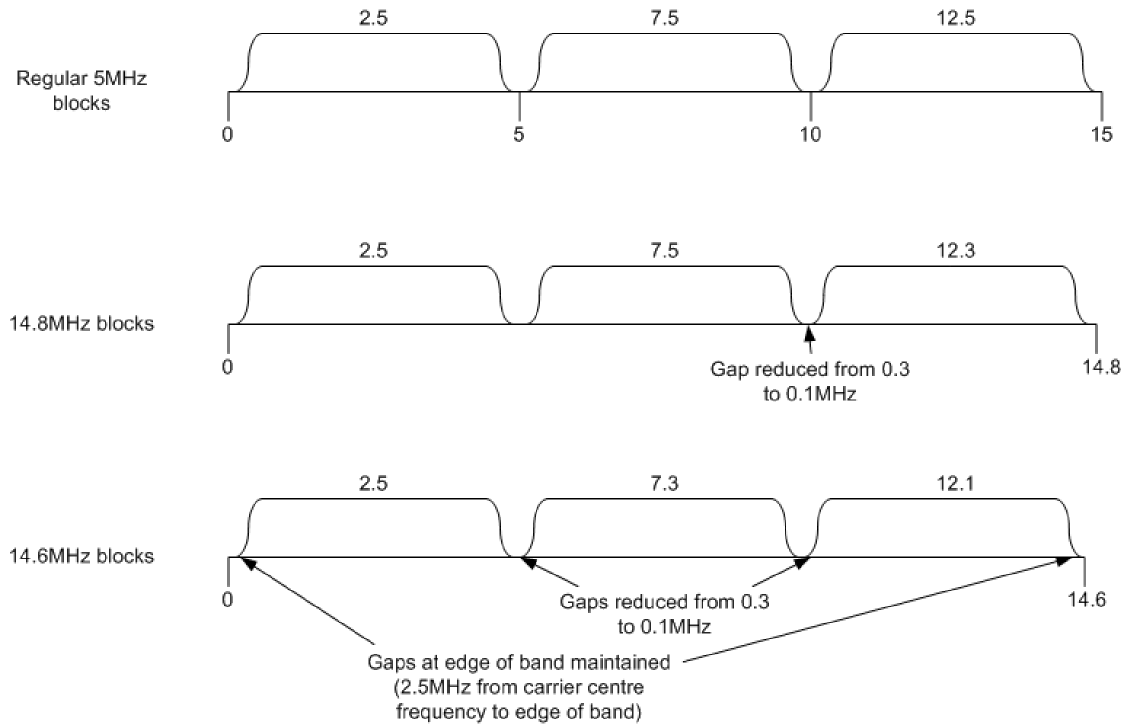
Three 3G carriers can therefore be arranged in practice as follows in a 14.6 MHz block as owned by Vodafone.

[1] 3GPP TS25.104, v12.1.0, Section 5.4.1, pg. 17.

[2] While the 3GPP standards state only "less than 5 MHz" (3GPP TS25.104, v12.1.0, Section 6.6.1.1, pg. 25; "The occupied channel bandwidth shall be less than 5 MHz based on a chip rate of 3.84 Mcps"), the product of PA Consulting computation delivers a more precise result of 4.685 MHz.

[3] 3GPP TS25.104, v12.1.0, Section 5.4.2, pg. 17; "The channel raster is 200 kHz for all bands, which means that the centre frequency must be an integer multiple of 200 kHz".

Figure 2: Possible arrangement of UMTS carriers within 2100 MHz band allocations of 14.8 MHz and 14.6 MHz respectively



There is no recommendation in the standards[4] that governs the separation between adjacent 3G carriers, which would prevent shifting carriers closer together. Adjacent channel interference may arise when carriers are placed too close together. The real effect will depend on the filtering performance of both transmitter as well as receiver in addition to further factors, not merely on the degree of separation. Further, filtering performance itself can vary by application and by equipment vendor.

The potential interference due to a separation of 4.8MHz (spacing increments are in multiples of 0.2MHz) rather than the nominal 5.0MHz is not considered material.

Although uplink and downlink signal modulation differs, the rules governing the bandwidth requirement apply equally for the purposes of treatment in this report to both uplink and downlink.

In conclusion, Vodafone and KPN can successfully arrange the same number of 3G carriers as each other in their sub-15 MHz blocks of 14.6 and 14.8 MHz respectively. Furthermore, all operators can arrange the same number of 3G carriers as each other in their respective block allocations.

1.2 The spectrum allocations do not confer advantage for delivery of LTE service

Potential unequal usage possibilities from the delivery of LTE do not arise as a result of the following conclusions:

- 2100MHz spectrum is a recognised LTE band

[4] 3GPP TR 25.942 v12.0.0 'Radio Frequency system scenarios' provides various recommendations for UMTS deployment but does not recommend carrier spacing.

- 3GPP standards allow the MNOs' current spectrum allocations to accommodate the same number of LTE carriers.

This section addresses these points in turn.

1.2.1 2100MHz spectrum is a recognised LTE band

All Dutch MNOs have already launched LTE service but in spectrum other than the 2100 MHz allocations.

The 2100 MHz band under discussion, specifically 1920 – 1980 MHz uplink and 2120 – 2170 MHz downlink, is officially defined in the 3GPP standard as an "E-UTRA operating band",[5] meaning that it is also a recognised LTE band.

2100 MHz spectrum can therefore be used exclusively to deliver LTE services in the Netherlands.

1.2.2 3GPP standards allow the MNOs' current spectrum allocations to accommodate the same number of LTE carriers

The LTE standard is not defined in the same way as the 3G standard. Whereas the 3G standard defines spectrum in 5 MHz blocks, the LTE standard defines 2100 MHz band spectrum in blocks of specific sizes of 5 MHz, 10 MHz, 15 MHz and 20 MHz.[6]

Yet further contrary to the manner in which 3G spectrum is utilised, an LTE spectrum block (of sizes listed above) is then parcelled into a number of sub-blocks called 'resource blocks'. A resource block has constant size of 180 kHz.[7] Whereas the nominal LTE spectrum block is of sizes listed above as multiples of 5MHz, the occupied bandwidth within any LTE spectrum block is calculated as a multiple of a set number[8] of the 180 kHz resource blocks.

Rather than multiplying up 180 kHz resource blocks however, the occupied bandwidth can simply be calculated as 90% of the spectrum block size. For example, a 15MHz LTE spectrum block would have occupied bandwidth of the aggregate 180 kHz resource blocks accounting for 90% x 15 MHz = 13.5 MHz.

Due to limitations in signal filtering, to each occupied bandwidth must be added an additional bandwidth amount of approximately 0.2 MHz (comprising 0.1 MHz at each end of the occupied bandwidth)[9] in order to arrive at the total bandwidth occupied. For the example 15MHz spectrum block, the 90% 13.5 MHz occupied bandwidth calculated then becomes 13.7 MHz to allow for the signal filtering limitations.

The diagram below depicts spectrum block size, the number of resource blocks fitting into each size, the resulting occupied bandwidth, and finally the occupied bandwidth with the addition for signal filtering limitation.

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[5] E-UTRA - Evolved UMTS Terrestrial Radio Access.

[6] 3GPP TS36.101 v12.0.0, Table 5.6.1-1, pg 27.

[7] 3GPP TS36.211 v12.3.0, Section 6.2.3, pg 60; "A physical resource block thus consists of […] 180 kHz […]".

[8] 3GPP TS36.101 v12.0.0, Table 5.6.1, pg 25.

[9] PA calculation based on the characteristics defined in 3GPP TS36.101 and 3GPP TS36.211, multiple pages; (i) rectangular window filtering of a 15 kHz sub-carriers gives -25dB at 90 kHz from the sub-carrier, (ii) summing multiple OFDM sub-carriers gives approx. -20dB at +/-100kHz from the edge sub-carrier.

Table 1: The occupied bandwidth for spectrum block sizes specified in the standards for 2100 MHz

Spectrum block size	5 MHz	10 MHz	15 MHz	20 MHz
Number of 180 kHz resource blocks	25	50	75	100
Occupied bandwidth	4.5 MHz	9.0 MHz	13.5 MHz	18.0 MHz
Occupied bandwidth allowing for signal filtering	4.7 MHz	9.2 MHz	**13.7 MHz**	18.2 MHz

Of interest is the 15 MHz spectrum block size. Vodafone has 14.6 MHz and KPN has 14.8 MHz, as opposed to the nominal 15 MHz block. From the table and preceding example calculations, it is clear that both Vodafone and KPN's allocations can comfortably accommodate the 13.7 MHz 'occupied bandwidth allowing for signal filtering' (highlighted in bold in the table) required to operate LTE service.

Furthermore, in light of occupied bandwidth requiring 90% of the block size in addition to signal filtering allowance, there is no advantage in T-Mobile's 10 + 10 MHz when compared to Vodafone and KPN's 15 MHz + 5 MHz. The occupied bandwidth totals for all three operators are the same.

In conclusion therefore, all MNOs are able to deliver the same number of LTE carriers within the current bandwidth allocations based on the 3GPP standards. The current spectrum allocations do not confer advantage to any MNO for LTE delivery.

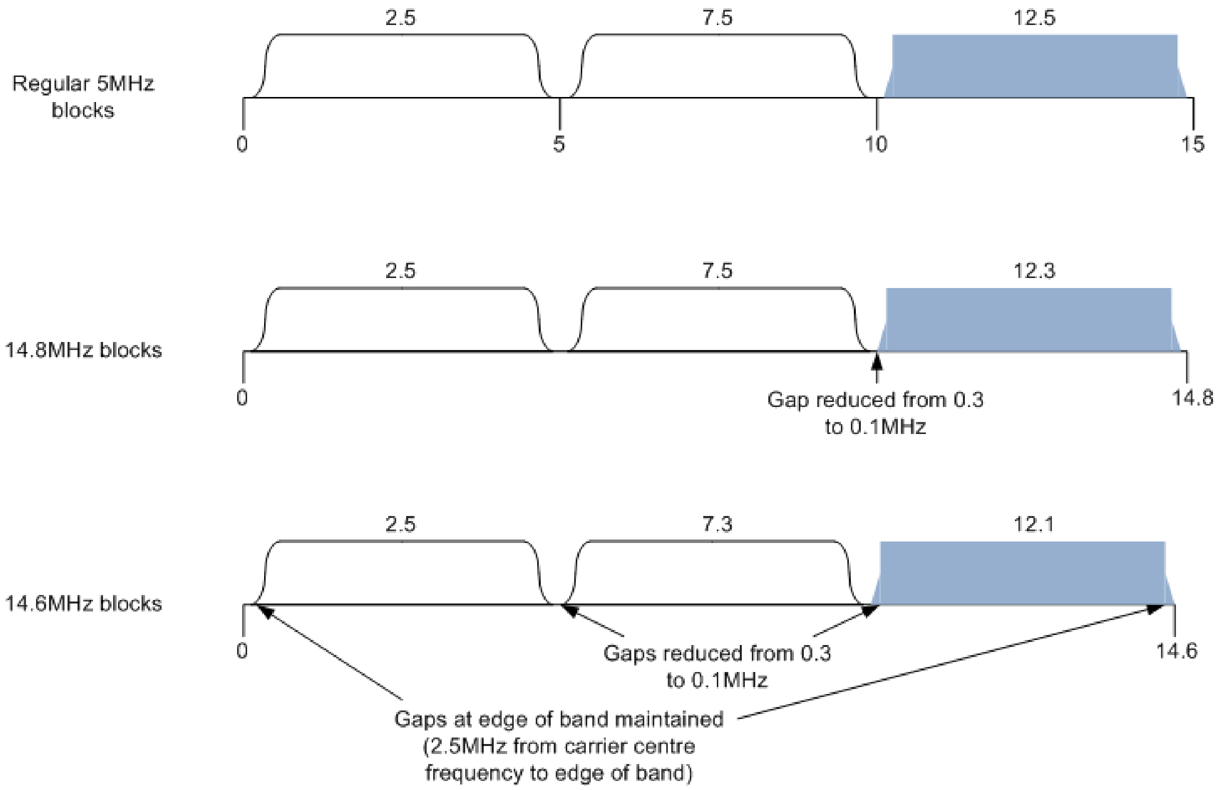
1.3 The spectrum allocations do not confer advantage during transition from UMTS to LTE

A transition period occurs, when MNOs seek to refarm 2100 band spectrum used for UMTS in order to deliver LTE service. During such transition, MNOs may seek to deliver both UMTS and LTE in various combinations.

The 3GPP standards outlined above, on which calculations of occupied bandwidths rely, continue to apply equally during such a transition phase.

The diagram below depicts how an LTE carrier and 2 UMTS carriers could be accommodated in both a 14.8 MHz and 14.6 MHz allocation respectively.

Figure 3: Possible arrangement of two UMTS carriers and one 5MHz LTE carrier within 2100 MHz band allocations of 14.8 MHz and 14.6 MHz respectively



In conclusion all MNOs are able to deliver the same number of blended UMTs / LTE carriers within the current bandwidth allocations based on the 3GPP standards. The current spectrum allocations do not confer advantage to any MNO for transitional blended UMTS / LTE delivery.

1.4 Recommendations contained in the CEPT report do not alter interpretation of the 3GPP standards

The 3GPP standard makes no technical recommendation of a minimum separation between UMTS and/or LTE carriers beyond those described in the previous two sections. Nevertheless, the European Conference of Postal and Telecommunications Administrations (CEPT) offers more specific recommendations in its Report 40 dated November 2010.[10]

CEPT's recommendations do not materially affect existing conclusions for the following reasons:

- CEPT's recommendations relate to ideal rather than real deployments.
- CEPT recommendations do not contradict the finding that no advantage accrues from current spectrum allocations for deployment of adjacent UMTS/LTE or adjacent LTE/LTE carriers.

These are individually addressed below.

[10] CEPT Report 40, "Compatibility study for LTE and WiMAX operating within the bands 880-915MHz/ 925-960MHz and 1710-1785Mz/1805-1880MHz (900-1800MHz bands)", pg 26, Table 14 and pg 28 Table 15.

1.4.1 CEPT's recommendations relate to ideal rather than real deployments

CEPT Report 40 is titled, "*Compatibility study for LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1710-1785 MHz / 1805-1880 MHz (900/1800 MHz bands)*". While it deals substantively with LTE and WiMAX abutting GSM at a time when WiMAX was more relevant, the report specifically also makes recommendations for the following, which are of relevance to this study;

- The operation of UMTS carriers abutting LTE carriers,[11] and
- The operation of LTE carriers abutting other LTE carriers.[12]

It should further be noted that the report addresses UMTS and LTE deployments in the 900 MHz and 1800 MHz bands, and not the 2100 MHz band under review here. Nevertheless, this study posits that the CEPT Report's findings may apply in the 2100 band.

The Report addresses specifically 'frequency separation between adjacent carrier centre frequencies'. In simple terms, it recommends that;

- [for UMTS abutting LTE] the distance between the centres of UMTS and minimum-5MHz LTE carriers be an integer multiple of 2.5 MHz.
- [for LTE abutting LTE] the distance between the centres of adjacent LTE carriers be the sum of half the nominal channel bandwidth of each of those adjacent LTE carriers.[13]
- For the sake of completeness, it should be pointed out that the CEPT report makes no recommendation for separation between UMTS channels.

This recommendation has potential to impact MNOs seeking to operate UMTS or LTE carriers that neighbour another LTE carrier in spectrum allocations of smaller size than the nominal size; namely those of Vodafone and KPN in the Dutch 2100 band.

Despite making such recommendations, the CEPT Report nevertheless points out that;

- [For LTE abutting both LTE and UMTS] the laboratory simulations underpinning CEPT's recommendations ride on the assumption of being *"in an urban area with uncoordinated deployment",*[14]

Further CEPT recommendations include the following statements;

- [For LTE abutting LTE], "[n]*o frequency separation* [is] *required between LTE channel edges between two neighbouring LTE networks*".[15] This suggests that no additional guard bands are required between two LTE carriers, above and beyond the nominal blocks size (e.g. 5, 10, 15, 20 MHz and so on).
- [For LTE abutting LTE], "[t]*he recommended technical conditions could be relaxed at national level based on agreement between operators*".[16]

The following sections of this review consider the impact of CEPT's recommendations in the scenarios potentially arising in the Dutch 2100 band, specifically in relation to Vodafone and KPN's respective 14.6 and 14.8 MHz allocations. Subject to those, an overarching conclusion suggests that the report's recommendations apply to *ideal* scenarios for operating LTE next to LTE or UMTS. In light of the aggregate recommendations quoted above, the Report makes concessions which would allow for different outcomes in un-ideal (practical) situations.

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[11] CEPT Report 40, Chapter 10, pg. 24 and on.

[12] CEPT Report 40, Chapter 11, pg. 26 and on.

[13] Wording based on CEPT Report 40, chapter 11.2, para 2, pg. 28.

[14] CEPT Report 40, [interference from LTE to UMTS] chapter 10.1, para 1, pg. 24; [interference from LTE to LTE] chapter 11.1, para 2, pg. 26 and chapter 11.2, para 1, pg. 28.

[15] CEPT Report 40, pg 3, Table – untitled.

[16] CEPT Report 40, pg 3, Table – untitled.

1.4.2 CEPT recommendations do not contradict the finding that no advantage accrues from current spectrum allocations for deployment of adjacent UMTS/LTE or adjacent LTE/LTE carriers

In considering the actual 2100 MHz implementations possible, one need review CEPT's recommendations only with respect to Vodafone and KPN's spectrum 14.6 and 14.8 MHz allocations. Other 2100 allocations are of standard / nominal size and as such channel spacing is not in question.

CEPT recommendations do not contradict the finding that no advantage accrues from current allocations for the following reasons;

- CEPT deals only with inter-MNO spacing
- Current spectrum allocations allow MNOs to adhere to CEPT recommendations
- CEPT in any case envisages potential for relaxing its carrier spacing recommendations at national level.

CEPT deals only with inter-MNO spacing

The CEPT report deals with a situation *"in an urban area with uncoordinated deployment".*[17] This relates only to carriers that have been independently set up and are hence un-coordinated.

Both UMTS and LTE carriers within an MNO's allocation will be coordinated by that MNO as a matter of course. Since coordinated, they therefore fall outside the scope of the CEPT report which deals with only uncoordinated situations.

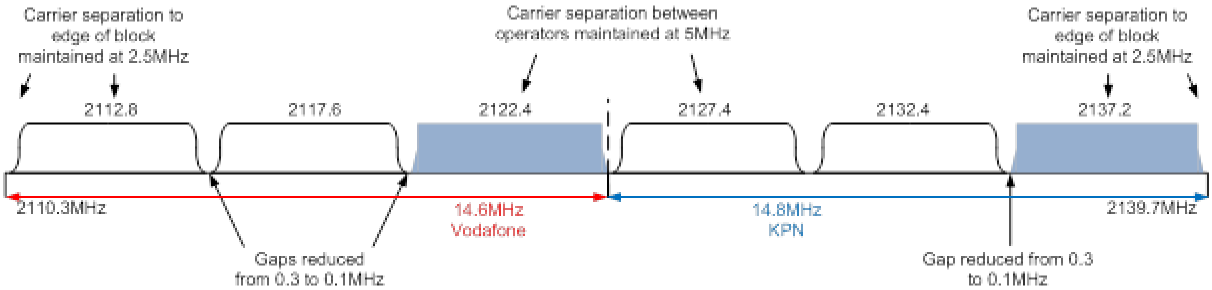
The CEPT report therefore deals only with inter-MNO and not intra-MNO spacing.

Current spectrum allocations allow MNOs to adhere to CEPT recommendations

Based on allowable intra-MNO carrier arrangement described in the previous sections for both UMTS and LTE, both the MNOs Vodafone and KPN with smaller than nominal 2100 allocations, can maintain CEPT's recommended spacing.

The standards allow both Vodafone and KPN to arrange their carriers in the manner described above, such that the gaps at the edge of their allocations are maintained at 2.5 MHz. With this 2.5 MHz spacing for both MNOs, the gap between their inter-MNO carrier centre frequencies is maintained at 5 MHz, and therefore satisfies CEPT's recommendation. This is depicted in the diagram below, for the inter-MNO spacing between Vodafone and KPN.

Figure 4: Possible inter-MNO arrangement of UMTS and LTE carriers within 2100 MHz band allocations of 14.8 MHz and 14.6 MHz respectively



[17] CEPT Report 40, [interference from LTE to UMTS] chapter 10.1, para 1, pg. 24; [interference from LTE to LTE] chapter 11.1, para 2, pg. 26 and chapter 11.2, para 1, pg. 28.

CEPT in any case envisages potential for relaxing its carrier spacing recommendations at national level

In practice, further factors may apply. As pointed out above, the CEPT report states in relation to inter-MNO interfaces that its "*recommended technical conditions could be relaxed at national level based on agreement between operators*".[16] A situation in which inter-MNO spacing were reduced is therefore not negated by the CEPT report. Instead, its recommendation provides for this situation, based on national MNO agreement.

1.5 Evolutions of the UMTS and LTE standards do not afford T-Mobile advantage that is material

Further factors merit consideration, specifically whether any advantage accrues based on current spectrum allocations through the ability to deliver the enhanced variants of UMTS and LTE standards as follows;

- Dual-cell (also termed dual carrier) HSPA
- LTE-A carrier aggregation.

While there is a difference in what the Dutch operators can offer in this regard, this study concludes as follows;

- T-Mobile's technical advantage in delivering DC-HSPA brought about by the spread of 2100 allocations is in reality not material.
- T-Mobile's technical ability to deliver DC-HSPA in combination with a single LTE carrier is non-material and off-set by other options
- No advantage accrues for potential delivery of LTE carrier aggregation.

This section addresses each of these points in turn.

1.5.1 T-Mobile's technical advantage in delivering DC-HSPA brought about by the spread of 2100 allocations is in reality not material

The spread of spectrum allocations may confer some technical advantage. This advantage occurs through the unequal ability to offer dual carrier 3G service. This potential advantage accrues for the following reasons:

- Delivery of dual cell 3G service favours T-Mobile's spectrum allocation
- User devices are capable of exploiting dual-cell 3G service.

Nevertheless, this advantage is mitigated for the following reason:

- While T-Mobile might differentiate marketing its service offer, subscriber benefit is likely limited.

Delivery of dual cell 3G service favours T-Mobile's spectrum allocation

Dual cell 3G technology (DC-HSPA) uses two carriers to deliver data at twice the rate of a single carrier. DC-HSPA can deliver peak data rates of 42 Mbps (downlink). A single 3G cell (carrier) can support a peak data delivery rate of only 21 Mbps. Dual cell HSPA can therefore support data delivery at twice the rate of single cell HSPA. There is no standard for triple cell HSPA.

In relating this technology to the circumstance under review, the term 'dual cell' can be understood as 'dual carrier' – the terms are used interchangeably for practical discussion.[18]

[18] Ericsson comments, "Dual carrier HSDPA operation (also known as dual cell HSDPA or DC-HSDPA)", para. 3, 2nd column, pg. 1; www.ericsson.com/res/thecompany/.../multi-carrier_hspa_evolution.pdf

A nominal 5 MHz block can accommodate one HSPA carrier. DC-HSPA technology requires aggregation of two HSPA carriers (or two cells, of one carrier each). The DC-HSPA standards allow for aggregation of *adjacent* carriers but not of non-adjacent carriers. In order to offer DC-HSPA service, an MNO therefore requires a 10 MHz or larger block of contiguous spectrum.

Table 2: Bandwidth requirement and performance by evolving 3G technology variants

3G technology variant	Carrier bandwidth	Peak data rate	Coverage in Netherlands
UMTS / HSPA	5 MHz	14 Mbps	99%
HSPA+	5 MHz	21 Mbps	99%
DC-HSPA+	10 MHz contiguous	42 Mbps	99%

T-Mobile has two separate allocations of 10 MHz blocks (10 MHz + 10 MHz) in the 2100 MHz band, whereas Vodafone and KPN have only one allocation that contains a 10 MHz block (they have nominal 15 MHz + 5 MHz each).

The allocation totals 20 MHz nominal per MNO, so each MNO can operate four 3G 5MHz carriers, representing a total HSPA capacity of 84 Mbps (4 x 21 Mbps).

However, T-Mobile could operate two DC-HSPA systems (2 x 42 Mbps), whereas KPN and Vodafone could operate only one such system (1 x 42 Mbps) plus two individual carriers (2 x 21 Mbps). The sum total capacity that all MNOs can deliver remains 84 Mbps but the peak data rate to a single user that any MNO can deliver is 42 Mbps. This remains the same for all operators.

The theoretical difference arises in the fact that T-Mobile could offer 42 Mbps to two users simultaneously whereas Vodafone and KPN could offer 42 Mbps to one user only, in addition to 21 Mbps to two further users. All of these data rates could only be achieved under ideal conditions and the figures in realistic usage conditions will be notably lower.

User devices are capable of exploiting dual carrier 3G service

While DC-HSPA is a 3GPP standard, not all standards are adopted. Where standards are adopted, they are not always adopted universally or at the same time. In order for subscribers to avail themselves of an MNO's DC-HSPA service, subscriber devices would need to support the standard.

The table below depicts the 3G capabilities of the most popular mobile data-capable devices in the Netherlands in a 2013 survey. All but one of the most popular devices could exploit DC-HSPA+ at that point. It is clear that feature sets once established are unlikely to regress.

Table 3: DC-HSPA+ capability of the most popular smart devices in the Dutch market[19]

Device type	HSPA+	DC-HSPA+
Samsung Galaxy S5 4G+	yes	yes
Samsung Note 4	yes	yes
Samsung Note Edge	yes	yes
iPhone 6	yes	yes
iPhone 5	yes	yes
Nokia Lumia 930	yes	yes

[19] www.telecompaper.com/pressrelease/samsung-dominates-dutch-smartphone-market--973962.

Nokia Lumia 830	yes	yes
Nokia Lumia 630	yes	**NO**
Huawei Asc Mat 7	yes	yes
LG G Flex 2	yes	yes
LG G3	yes	yes
Nexus 6	yes	yes
HTC one M8	yes	yes
Sony Xperia Z2/Z3	yes	yes

While T-Mobile might differentiate marketing of its service offer, subscriber benefit is limited

Illustrated at the start of this section is the advantage that T-Mobile could have in the future, if choosing to deploy DC-HSPA. This advantage is in the physical layer, meaning it exists technically. The technical advantage must however be considered in reality. The advantage is largely non material for the following reasons;

- T-Mobile might be able to exploit a marketing advantage
- Subscriber benefit is in practice broadly negligible.

These points are addressed individually below.

T-Mobile might be able to exploit a marketing advantage

MNO competitive marketing relies heavily on exploiting theoretical coverage and capacity differences.

In the early mobile market, MNOs competed on coverage differences in tenths of percentage points (of population covered). Coverage competition re-emerges with every new generation of mobile technology.

With the launch of LTE, MNOs compete on LTE coverage. This has eclipsed competition on the basis of 3G coverage and the latter no longer occurs.

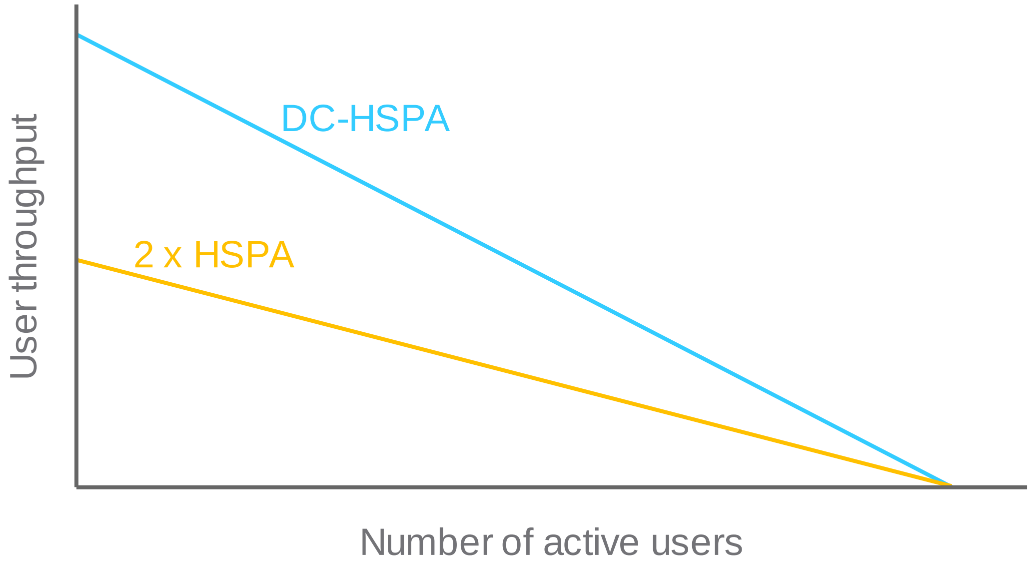
Competition on the basis of capacity is however high, specifically the data download speeds available to subscribers. MNOs will use theoretical speeds, rather than actually achievable speeds. Were T-Mobile did launch DC-HSPA using 2 x 10MHz blocks, compared to its competitors 1 x 10MHz block, it could not claim that its 3G service was twice as fast. As stated above, all operators would have a theoretical peak 3G download speed of 42 Mbps. It is conceivable that a marketing message could be constructed to suggest it could offer ‘a better 3G data speed to more subscribers at the same time’ or that it could suffer less speed degradation during rush hour or similar. Given the lack of message clarity, the advantage appears modest. Further, MNOs do not compete notably on 3G capacity anymore. 3G marketing about capacity has too been relatively eclipsed by the launch of LTE.

It is important to note that the ability to market this uncertain 3G competitive difference is itself unlikely sufficient reason to launch the DC-HSPA service.

Subscriber benefit is in practice broadly negligible

Subscriber ability to benefit from T-Mobile’s service delivery over two DC-HSPA systems versus Vodafone and KPN’s delivery over one DC-HSPA system as well as two additional standard HSPA carriers is negligible. Peak data rates apply with only one theoretical subscriber within the cell, benefitting from the full throughput. Where the real situation arises of more than one subscriber within a cell, the peak data rate is quickly reduced as a function of the number of subscribers. The aggregate subscriber data rate (throughput) for 2 x HSPA carriers versus a DC-HSPA system eventually tends to parity. This concept is depicted in the diagram below. This means that the peak data rate actually seen by any individual subscriber will be less than 21 Mbps, regardless of whether they are served via a single HSPA carrier or via a DC-HSPA carrier pair.

Figure 5: Notional comparison of difference in subscriber experience using HSPA versus DC-HSPA[20]



For the difference between T-Mobile's technical advantage to be apparent in the service quality to a subscriber, the following set of conditions would all need to apply simultaneously:

- T-Mobile has deployed two DC-HSPA carrier pairs, while Vodafone and KPN have each deployed one DC-HSPA system.
- Each operator has exactly two subscribers attempting to download content at the maximum data rate possible, in the area specifically served by the HSPA systems in the previous bullet.
- The applications serving that content to each subscriber are capable of exploiting DC-HSPA to deliver content at a higher rate.
- Those particular subscribers and their handsets are making use of DC-HSPA and not another technology, for example HSPA, DB-DC-HSPA or LTE.

The confluence of circumstances is ideal not real. In reality, a cell will contain many active users. Further, subscribers routinely keen to exploit fast mobile data or applications offering/ requiring fast data connections are more likely to have signed up for LTE service. For these reasons, T-Mobile's technical advantage does not translate into a material one.

1.5.2 T-Mobile's technical ability to deliver DC-HSPA in combination with a single LTE carrier is non-material and off-set by other options

T-Mobile's ability to offer DC-HSPA service also exists in a differently configured combination but again, the benefits derived through a technical advantage are not material. This conclusion is supported by means of the following three points;

- T-Mobile can deliver DC-HSPA (or simply HSPA) in conjunction with a 10 MHz LTE carrier
- Real benefit in delivering a single 10 MHz LTE carrier over two 5 MHz carriers is not material
- Vodafone and KPN have options that T-Mobile does not.

These are addressed in turn.

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[20] Diagram based on Ericsson diagram, www.ericsson.com/res/region_RASO/docs/2012/ericsson_dc_hspa_paper.pdf, pg 5.

T-Mobile can deliver DC-HSPA (or simply HSPA) in conjunction with a 10 MHz LTE carrier

Other options also exist, in addition to T-Mobile's delivery of two DC-HSPA systems in its 2100 spectrum allocation. T-Mobile could deliver only one such DC-HSPA system (requiring a contiguous 10 MHz block) in addition to delivering a 10 MHz LTE carrier (requiring its other contiguous 10 MHz block). It could also simply deliver standard HSPA (necessarily as two 5 MHz carriers) in combination with 10 MHz LTE (as a single carrier); 10 MHz 3G plus 10 MHz 4G.

Vodafone and KPN can also deliver one DC-HSPA system or standard HSPA with 10 MHz (from their respective, nominal 15 MHz blocks). In conjunction, they can each deliver two individual 5 MHz LTE carriers (using the remaining 5 MHz from their nominal 15 MHz blocks in addition to their separate 5 MHz blocks) instead of a single 10 MHz LTE carrier.

Real benefit in delivering a single 10 MHz LTE carrier over two 5 MHz carriers is not material

As part of such an arrangement, T-Mobile can deliver a 10 MHz LTE carrier, and Vodafone / KPN can only 5 MHz + 5 MHz LTE. T-Mobile appears to have a technical advantage. The tangible benefit of this technical advantage is non-material. This is for the same reasons as described in the previous sub-section (in relation to operating two DC-HSPA systems compared with one system).

All three MNOs can deliver LTE over a total 10 MHz; the total LTE service capacity offered to subscribers is therefore identical. A single 10MHz LTE carrier will have essentially the same performance as two 5MHz LTE carriers since in any commercially operational network there will be many users per cell, who have the total data rate divided between them. The effect of the higher data rate obtainable from a 10MHz LTE carrier compared to a single 5MHz LTE carrier is largely theoretical as it assumes one and only one user per cell (laboratory conditions).[21]

The technical advantage through the specific combination arrangement of DC-HSPA or HSPA and LTE carrier(s) is therefore not material.

Vodafone and KPN have options that T-Mobile does not

While related specifically to HSPA delivery in combination with LTE delivery, the example above is only one possible permutation for service delivery over current spectrum allocations. There are other possible technical permutations.

A technical option conversely open to both Vodafone and KPN and not to T-Mobile is the delivery of LTE over a single nominal 15MHz carrier. Both Vodafone and KPN have nominal 15 MHz spectrum blocks and could deliver a single LTE carrier in this. T-Mobile can only offer a maximum 10 MHz LTE carrier before having to rely on an additional carrier in a non-contiguous block.

The use of various permutations depends on operator strategy. That strategy relates not only to the 2100 band, but each MNO's holdings in other bands too. Speculation in respect of the potential technical (but not necessarily material) merits available through various theoretical service and carrier combinations does not therefore drive definitive argument in concluding that unfair advantage is conferred.

1.5.3 No advantage accrues for potential delivery of LTE carrier aggregation

Operators deploying LTE in the 2100 MHZ band will do so using the latest LTE standard, LTE-Advanced (LTE-A). The LTE-A standard makes provision for 'LTE carrier-aggregation'. Carrier

[21] The graphic presented in Figure 5 applies notionally in this context as well, where references to [HSPA] / [DC-HSPA] are replaced with references to [5 MHz + 5 MHz LTE carriers] / [10 MHz LTE carrier].

aggregation allows the use of carriers in non-contiguous spectrum to deliver increased user net data rates. This can improve the user experience for high bandwidth services

Vodafone and KPN have equal opportunity to use 2100 MHz in conjunction with their current allocations in other bands for LTE-A carrier aggregation (CA). T-Mobile has fewer opportunities than both Vodafone and KPN. However, this situation arises from T-Mobile's allocations in other bands, not in the 2100 MHz band. This is addressed under the following sub-headings;

- LTE carrier aggregation at 2100 MHz relies on pairing with other bands
- Technical advantages for inter-band aggregation do not relate to holdings in the 2100 MHz band
- In the near future, device availability limits the usefulness of carrier aggregation in practice
- The spread of spectrum allocations does not confer advantage for delivery of LTE carrier aggregation.

LTE carrier aggregation at 2100 MHz relies on pairing with other bands

The standards allow for two fundamental approaches to LTE-A carrier aggregation.

- Intra-band carrier aggregation
- Inter-band carrier aggregation.

Intra-band carrier aggregation

Intra-band carrier aggregation in the 2100 MHz band is standardised only for spectrum blocks of (15 MHz + 15 MHz) and (20MHz + 20 MHz).[22] The standard allows for non-contiguous such blocks. However, none of the Dutch MNOs hold licenses for this amount of spectrum in the band. No further spectrum in the 2100 MHz band is recognised as LTE spectrum and no Dutch MNO can therefore acquire more spectrum to achieve an allocation of sufficient size that would support the intra-band aggregation options. Consequently, this will not apply in the Netherlands and no unequal advantage can accrue.

There is therefore benefit from neither the current spectrum allocation sizing, nor the current spread of allocations for delivery of LTE-A carrier aggregation.

Inter-band carrier aggregation

The LTE-A standard makes provision for 2100 MHz inter-band aggregation of carriers at various bands: 800, 1800, 2100 and 2600 MHz.[23]

The 2100 MHz band is standardised as an aggregation with any of the above bands. These are the standards-based pairings involving 2100 MHz and another European cellular band and consequently the pairings relevant for review.

Technical advantages for inter-band aggregation do not relate to holdings in the 2100 MHz band

Consideration is required of MNO spectrum allocations at the various frequencies listed above in conjunction with those at 2100 MHz. These are individually addressed below.

No advantage arises through aggregation with 800 MHz

Inter-band aggregation for the 2100 + 800 MHz bands is standardised for channel permutations that consist of the following bandwidths:

- [5, 10, 15 or 20 MHz in the 900 band] aggregated with [5, 10, 15 or 20 MHz in the 2100 band].

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[22] 3GPP TS36.101 v2.0.0 Table 5.5.A-1 (intra-band).

[23] 3GPP TS36.101 v2.0.0 Table 5.5.A-2 (inter-band).

MNO allocations in the 800 band are 10 MHz each for KPN and Vodafone. T-Mobile has no spectrum in the band. Vodafone and KPN have equal opportunity to deploy CA at 2100+800 MHz whereas T-Mobile has no such opportunity. This technical advantage arises from holdings at 800 MHz, therefore no advantage accrues from 2100 holdings.

No advantage arises through aggregation with 900 MHz

Inter-band aggregation for the 2100 + 900 MHz bands is standardised for all channel permutations that consist of the following bandwidths:

- [5 or 10 MHz in the 900 band] aggregated with [5 or 10 MHz in the 2100 band]
- [5 or 10 MHz in the 900 band) aggregated with [5, 10, 15 or 20 MHz in the 2100 band].

The two entries bulleted above are listed distinctly in the standards for separate device classes but for the purposes of this report, it is sufficient to understand simply that 5 or 10 MHz at 900 can be aggregated with 5, 10, 15 or 20 at 2100.

In the 900 band, Vodafone and KPN hold 10 MHz each whereas T-Mobile holds 15 MHz.

A number of observations regards these spectrum allocations can be made:

- The standards allow for inter-band CA of a maximum of 10 MHz from the 900 band in combination with 2100. All MNOs have at least 10 MHz in the 900 MHz band. As a result, no advantage arises.
- T-Mobile has an additional 5 MHz at 900. Argumentation in favour of potential advantage arising through this is aligned to the results achieved in the 2012 auction for 900 MHz spectrum, not in relation to current holdings at 2100 MHz.
- The standards allow for combinations of non-adjacent 5, 10, 15 or 20 MHz blocks at 2100, so block adjacency is no advantage. Further all MNOs have nominal 20 MHz allocations at 2100. As a result of both points, no advantage arises.

Refarming of 900 MHz to launch LTE service in the period before 2021 is in any case unlikely

No advantage arises through aggregation with 1800 MHz

Inter-band aggregation for the 2100 + 1800 MHz bands is standardised for channel permutations consisting of the following bandwidths:

- [5, 10, 15 or 20 MHz in the 1800 band] aggregated with [5, 10, 15 or 20 MHz in the 2100 band].

In the 1800 band, Vodafone and KPN hold 20 MHz whereas T-Mobile holds 30 MHz.

The standard allows for CA using a maximum of 20 MHz at 1800. All operators hold at least 20 MHz at 1800. No advantage arises.

No advantage arises through aggregation with 2600 MHz

Inter-band aggregation for the 2100 + 2600 MHz bands is standardised for channel permutations consisting of the following bandwidths:

- 10, 15 or 20 MHz in the 1800 band] aggregated with [5, 10, 15 or 20 MHz in the 2100 band].

In the 2600 band (FDD), KPN and Vodafone hold 10 MHz and T-Mobile holds 5 MHz.

KPN and Vodafone have equal opportunity for CA at 2100 + 2600 whereas T-Mobile has no such opportunity. This technical advantage arises from the MNOs' holdings at 2600 and their holdings at 2100 do not give rise to the advantage.

No advantage arises through specific permutations or non-standard deployments

It is conceivable that some permutations of specific blocks at 2100 with specific blocks in other bands are preferable in terms of future availability of devices able to exploit such CA service. This will depend on which combinations chipset manufacturers introduce for manufacture. Chipset feature-set roadmaps are commercially sensitive and not available. It is however credible to state that all combinations currently have equal merit and therefore no specific advantage arises from the current arrangement of 2100 MHz allocations.

Dutch MNOs could pursue CA strategy that is non-standard in order to better exploit their 2100 MHz spectrum holdings. Such a non-standard deployment could comprise (10 + 10 MHz) or (15 + 5 MHz) across 2100 MHz and other bands. This is unlikely. There is considerable risk in deployment, operation, support and future upgrade paths for non-standard deployments. Further, the small size of the Dutch market does not commercially merit bespoke equipment/ device specifications.

In practice, device availability restricts the usefulness of carrier aggregation in the near future

Historically the rollout of new cellular technologies has been constrained in practice by the (i) availability and (ii) subsequent adoption of mass-market user devices. It is reasonable to assume the same will be the case for CA.

A recent report from the Global Mobile Suppliers Association states that 2,218 different LTE user devices were available worldwide in the fourth quarter of 2014.[24] However, only 16 (or 0.7%) of total LTE devices were ‘category 6’, meaning that they are capable of exploiting CA service.

Further restricting the potential update in the near term, the LTE-CA capable device will need to support the specific permutation of bands and spectrum blocks that an operator wishes to use since manufacturers are very unlikely to cater for all, not least at the outset of such service deployment.

While the number of category 6 devices available will increase over time, it will lag behind the number of ‘simple’ LTE + HSPA devices. As a result, the commercial advantages and disadvantages arising from the ability to deploy CA in the network will be less than for deploying standard LTE or HSPA in that same 2100 MHz spectrum during the period to 2021 under review.

1.6 The spread of spectrum allocations does not confer advantage

While the distance between the Dutch MNO allocations is various, none has a single, contiguous block. All operators instead have two individual blocks. The distance between Vodafone’s blocks is nominally 30 MHz, whereas the distance between both KPN and T-Mobile’s allocated blocks is 10 MHz.

As operators seek to move from UMTS provision to blended UMTS and LTE provision, they may incur additional costs and the effect of the allocation spread (the gap between an MNO’s respective blocks) merits some consideration in this regard.

While the details of what each MNO has deployed are site-specific, we conclude that the spread of spectrum does not confer advantage for the following reasons:

- Radio units are not technology specific
- Antennas cover the full 2100 band
- The need for any additional filtering affects all the operators.

We address these in turn below.

1.6.1 Radio units are not technology specific

A modern base station will address the full 2100 band, but be configured for specific frequencies. The gap between spectrum block allocations has no material effect on the cost of radio units.

[24] ‘Status of the LTE Ecosystem’, update of October 2014, www.gsacom.com/news/gsa_417.php.

Where MNOs seek to change the use of carriers from UMTS to LTE, this may or may not require further radio unit investment by the MNO, but this is not dependent on the spread between spectrum allocations. It instead depends on each MNO's product strategy at the time of previous deployment.

If an MNO has previously made a product selection that caters for both UMTS and LTE, the radio unit will not require physical changes that incur additional cost. Where the MNO has not made this product choice and must revisit sites to effect upgrade in order to deliver LTE, this is unrelated to the spread of spectrum allocations.

1.6.2 Antennas cover the full 2100 band

Antenna equipment is inert. A 2100 band antenna will typically cover the full 2100 band, and not only sub-frequencies within it. A brief review of manufacturer catalogues of 2100 MHz band antennas shows in one case, an offer of in excess of 150 different types of antenna, where each one of these covers the full band. Antennas covering the full 2100 band were also substantially available at the time of initial licensing.

Further, antennas operate independently of the technology served over the antenna. A move from UMTS to LTE provision within the same band does not merit an antenna change. Permutations in an MNO's UMTS and/or LTE offer at various combinations of 2100 band sub-frequencies does not therefore require antenna change, depending on the spread of spectrum blocks.

It is conceivable that an MNO has historically made antenna product choices that serve only specific sub-frequencies in the 2100 band although this would not be typical. In such a circumstance, where an antenna therefore requires upgrade as the MNO seeks to refarm some of its allocation from UMTS to LTE service, this upgrade relates to MNO's product strategy and not the spread of spectrum blocks.

1.6.3 The need for any additional filtering affects all operators

Where one MNO has two blocks of non-contiguous spectrum whereas a competitor has contiguous spectrum, the former can incur greater cost through needing to deploy more filtering equipment. It would typically deploy one filter for each of its two, non-contiguous blocks. Conversely, the latter MNO requires only one filter in total for its contiguous block.

This case would typically apply only to the subset of sites as follows;

- Sites which are shared by competitors or in immediate proximity to each other. The proximity of the two operators' transmitters and receivers at such sites would require the application of filters to prevent interference.
- Sites where the operator of two, non-contiguous blocks is operating a carrier at frequencies in each of its two blocks, but not where it operates a carrier in only one of the blocks.

While the distance between the Dutch MNO allocations is various, none has a single, contiguous block. The potential requirement for additional filtering described therefore applies to all MNOs. Variation 'on the ground' will depend on the permutations of how each MNO decides to operate its carriers per site.

The investment in such filtering is however broadly a sunk cost. The cost of filters has already been incurred in network deployment for UMTS. Filters comprise inert, solid metal components. Deployment of the filters is independent of whether used for delivery of UMTS or LTE service; they are frequency specific and not technology specific. The filter can remain the same, irrespective of MNO shifting of carriers from delivery of UMTS to LTE.

Specific situations may call for point upgrade or change-out of components but this does not apply universally and does not therefore confer any advantage. Further, a non-symmetrical shift towards increased site-sharing by two of the three MNOs may require deployment of more filtering equipment. One might consider treating such costs as part of the new site-sharing strategy however, rather than as costs related to comparative gaps between spectrum holdings. Filter hardware costs associated with increased site sharing are minor when considered in light of the other costs of network sharing.

In conclusion, the filter cost for an MNO having two spectrum blocks allocations will be increased by effectively having two separate filters versus one filter for a an MNO with a single allocation. The gap between the two allocations however has no material effect on the cost of the filter. As all MNOs have two allocations, the difference in gaps between them provides no cost advantage even if they do need to be replaced for some unforeseen reason.

1.7 It is unlikely that the period 2017 – 2021 will see changes that alter existing conclusions

There is little reason to re-consider the conclusions drawn above in light of further factors that could occur in the period under review for the following reasons:

- No additional spectrum is earmarked for release in the period 2017 – 2021
- Additive refinement to the 3GPP standards is not likely to see operational impact in the period 2017 – 2021.

These are addressed below.

1.7.1 No additional spectrum is earmarked for release during the period 2017 – 2020

The release of further spectrum could have the effect of creating a new advantage or conversely diluting any existing advantage.

The current spectrum allocations do not confer any unilateral advantage for LTE deployment and the release of new spectrum could therefore only have the effect of creating rather than negating advantage.

There is no additional recognised LTE spectrum in the 2100 MHz due for release.

More broadly the release of spectrum at other bands could create advantage with respect to possible carrier aggregation permutations, but such advantage would relate to that spectrum rather than the 2100 MHz holding.

There is in any case no LTE spectrum earmarked for release before 2020.

1.7.2 Additive refinement to the 3GPP standards is not likely to see operational impact in the period 2017 – 2020

The 3GPP standards evolve. Such evolution typically results in additive rather than retrospective adjustment. There is therefore no basis on which to believe that retrospective adjustment of standards will undermine the conclusions already drawn.

Additive adjustment to the standards could however facilitate re-consideration of conclusions drawn. Nevertheless, such adjustment takes significant time to percolate through into operational use;

- There are currently no changes to the 3GPP standards envisaged (that would negate the existing conclusions in this report).
- Where recommendations are that the 3GPP standards do change, not all changes proposed in the new release are actually taken forward and adopted.
- Where new standards are adopted, it takes time for equipment and device manufacturers to carry out research and development in order to press those new standards into production.

- Further delay occurs between equipment availability and commercial deployment.
- Once commercially deployed, subscriber uptake (and therefore benefit) takes time.

It is therefore unlikely that any additive changes to the 3GPP standards will see operational implementation before 2020 and hence impact conclusions here.

2 IS THE ANSWER DIFFERENT IF THE 2100 BAND IS EXTENDED TO 60 MHZ AS A STARTING POINT, IN ORDER TO FACILITATE A POSSIBLE SWAP?

The question can be understood as a theoretical move from the current aggregate 59.4 MHz of spectrum licensed in the 2100 MHz band, to a position in which a full 60.0 MHz block is licensed. This requires the addition of a total of 0.6 MHz. This is achieved by supplementing both the allocations of licensees at each end of the current block by 0.3 MHz of additional spectrum; namely Vodafone and T-Mobile. This is depicted in Figure 6 below;

- Vodafone's allocation at the lower end of the band would increase from 14.6 to 14.9 MHz
- T-Mobile's allocation at the upper end of the band would increase from 10.0 to 10.3 MHz.

Figure 6: Theoretical expansion of current 2100 MHz spectrum allocations to a block of 60 MHz (uplink)

	Block 1		Block 2		Block 3		Block 4		Block 5		Block 6	
Operator	Vodafone		KPN		T-M 10MHz		KPN 5MHz		Voda 5MHz		T-M 10MHz	
Range	1920.3	1934.9	1934.9	1949.7	1949.7	1959.7	1959.7	1964.7	1964.7	1969.7	1969.7	1979.7
Total BW	14.6		14.8		10		5		5		10	

	Block 1		Block 2		Block 3		Block 4		Block 5		Block 6	
Operator	Vodafone		KPN		T-M 10MHz		KPN 5MHz		Voda 5MHz		T-M 10MHz	
Range	1920.0	1934.9	1934.9	1949.7	1949.7	1959.7	1959.7	1964.7	1964.7	1969.7	1969.7	1980
Total BW	14.9		14.8		10		5		5		10.3	

Such a move may appeal to those standing to gain additional spectrum. However, the conclusions from Question 1 in the previous chapter suggest that MNOs are currently not materially disadvantaged; the addition of spectrum does not therefore address material disadvantage. Nor does it create additional advantage.

Such a move would make the amount of spectrum held by Vodafone and KPN more similar. Importantly though, Vodafone would still have 14.9 MHz – an amount still below a nominal 15 MHz figure. T-Mobile would retain the position of holding more spectrum than Vodafone or KPN.

The addition of 0.3 MHz at each end of the currently licenced block does however offer the basis for the potential further move, of MNOs swapping spectrum in order to create contiguous blocks of 20 MHz. This further move to such a contiguous 20 MHz block arrangement is depicted in Figure 7 below.

Figure 7: Theoretical 2100 MHz (uplink) spectrum rearrangement into contiguous 20 MHz blocks

Illistrative	Block 1		Block 2		Block 3	
Operator	Vodafone		KPN		T-Mobile	
Range	1920.0	1940.0	1940.0	1960.0	1960.0	1980.0
Total BW	20		20		20	

Operations in a contiguous 20 MHz allocation may offer some appeal to one or all MNOs. There is potential benefit to all three Dutch MNOs from such a contiguous arrangement and they may therefore have incentive to bring about such a change, where this is an option. This cannot however be categorically stated, since it relies on numerous factors, not least each MNO's own cost-benefit analysis

This analysis would consider not only the costs and benefits in bringing about such a shift in 2100 band spectrum, but also whether such investment achieves better return from investment in other bands, in which the operator may also seek to deliver national LTE services.

3 IF ANSWER TO Q1 IS AFFIRMATIVE: TO WHAT EXTENT DO DIFFERENT USE POSSIBILITIES LEAD TO DIFFERENT VALUES?

The answer to Question 1 is not affirmative. Use possibilities are currently broadly equal for the reasons identified in the answer to Question 1. No *different* use possibilities are therefore identified. Since no different use possibilities are identified, there are no materially differentiated values.

4 WHAT APPROXIMATELY ARE THE COSTS OF MAKING 2100 MHZ LICENSES CONTIGUOUS (FOR AN ALREADY-MODERN NETWORK)?

Re-alignment of spectrum between operators incurs costs for all MNOs. While modern networks are software-configurable, spectrum shifting incurs additional hurdles in filtering and project management. Costs are likely to accrue in the tens of millions of Euros. We address these topics under the following headings:

- Modern networks have remotely re-configurable base stations
- Filtering upgrades are likely required on shared sites
- Such a project requires project planning and management
- National costs may fall in the order of €40m.

4.1 Modern networks have remotely re-configurable base stations

UMTS and LTE equipment includes highly reconfigurable line-cards in the base station equipment. This reconfiguration is software-driven and can therefore be achieved remotely from an MNO's Network Operations Centre (NOC). This remote activity prevents the de facto need to visit each site to effect a physical change, in order to implement the shifting in frequencies that would allow each operator a contiguous 20 MHz allocation.

Nevertheless, some of the UMTS equipment deployed in the network is now likely to be ten to twelve years old. It is conceivable that some sites are therefore carrying older line-cards and that these may indeed require a site visit to effect an equipment upgrade. We could envisage that such a situation might apply to a nominal 5% of sites. Such work would be subsumed into the cost of filter-swapping work that is described in the next point.

4.2 Filtering upgrades are likely required on shared sites

In many cases, MNOs share sites but deploy their own base station equipment (specifically transmitters and receivers) in close proximity to each other. In such instances, MNOs have likely deployed filters additional to those in the base stations in order to prevent mutual interference. Such additional filters are highly tuned and therefore frequency specific. If the carrier frequencies are shifted around, these filters will require physically replacing. This applies irrespective of technology: UMTS or LTE.

Such filters cost in the region of €2,000 to €4,000 each. We would expect a 3-man team to effect this change on two sites per day. Using a nominal fully-loaded labour cost of €700 per person per day, the labour might therefore cost €1,000 per site. Including the filter brings this sum to €4,000.

Assuming 60% of approximately 5,000 sites are on shared sites and could require a filter swap, the total field cost could equate to €12 million.

It should be noted that filters do not require swapping on every site. Vodafone for example, would need only to move its 5 MHz carrier down to align with the location of its existing nominal 15 MHz allocation. If that 5 MHz carrier is not operated at a particular site, then a filter swap will not be required. As such, the approximate costs calculated represent an upper band and actual costs will be lower, and vary by MNO.

4.3 Such a project requires project planning and management

Not only does a project such as the suggested spectrum re-ordering require each MNO to plan, but such planning must be coordinated between all MNOs. Each must coordinate not only their software changes at the NOC, but also coordinate changes effected at the site. Sites activities will be planned by cluster and region.

The further requirement for cross-border coordination is likely. A shift of only 0.3 MHz would likely not require it, but the shift envisaged to create 20 MHz contiguous requires shifting whole carriers. Neighbouring, cross-border sites will have coordinated on the basis of specific carriers; they will have planned base station locations, frequency and transmitted power into their coverage plans, and vice versa. A new round of coordination may therefore be required.

Such central planning and remote configuration activities could reasonably achieve 10 sites per day. To address approximately 5,000 sites might therefore take 500 man days or 1.5 years' worth of working days. The activities could be achieved by internal resourcing rather than external specialists and as such, per day costs are lower.

Between two and four FTEs may be required and we would expect an MNO to set aside approximate but conservative costs of

- €0.5 million for changes effected from the NOC
- A further €1 million for planning and project management office (PMO) activities.

4.4 National costs may fall in the order of €40 million

Costs of €12 million for site-based activities in addition to aggregate costs of €1.5m for central activities, totals €13.5 million. This cost is for one MNO but each of the three MNOs would need to carry out the same activities and one needs to triple the amount.

This therefore gives rise to a total approximate cost of €40 million. It should be noted that this represents an approximate upper band on costs for the reasons described.

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