LICENCE STUDY

STUDY ON THE COVERAGE OBLIGATION FOR LICENCES AND THE TRANSITION PERIOD FOR LICENCES IN THE 2100 MHZ BAND

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EXECUTIVE SUMMARY

The mobile market in the Netherlands will soon see the licensing of 700MHz spectrum as well as the re-assignment of 2100MHz spectrum. To better understand some uncertainties and safeguard the service level experienced by mobile subscribers, the Ministry of Economic Affairs and Climate Policy (the Ministry) has posed several questions, which are the subject of this study. These questions relate to current and prospective future service levels. This study contains PA's response to these questions. The Ministry will consider this study as one of the inputs to its regulatory decision-making.

Each of the four questions and PA's response to each question is summarised here.

QUESTION 1: What is the level of service quality (in terms of speed and capacity) that the current operators can offer throughout the country within their current spectrum portfolio?

In determining the minimum service level that is currently achievable to users in the Netherlands today, it is appropriate to apply a probability weighting. This is to normalise the likely minimum experience through exclusion of infrequent results that would serve to skew the calculated minimum to such a low level that it is then unreflective of what the Mobile networks can deliver. Further, it would subsequently render any regulatorily-imposed future minimum service level unhelpfully and artificially low.

PA believes that a probability level of 95% is appropriate, and we propose that the Ministry adopts this level both for calculating the current experience, and any future minimum service level condition. This probability is applied to service levels which we define as follows:

- *Minimum* - a 95% probability of a user experiencing at least this level of service. This level of service quality is most likely to apply at the cell edge in suburban areas when a user is competing with other users for network capacity, and therefore does not have access to the maximum available bandwidth of the service;
- *Average* - the more typical experience of an MNO's users across the country, with a 95% probability of a user experiencing this average level of service across all bands and across the Netherlands generally; and
- *Maximum* - the theoretical maximum experience of a single user, optimally located within the cell when a user is not competing with other users for network capacity, and so has access to the maximum available bandwidth of the service. This maximum will be constrained by the ability of the handset to manage the speeds offered by the network. This level of service quality is most likely to apply in an urban area.

The levels of service quality that mobile subscribers currently experience across the Netherlands with a 95% probability as minimum, average and maximum are described here and set out in the table below. The minimum is 4.1 Mbps in the downlink and 0.7 Mbps in the uplink. The weighted average across all operators is 58.7 Mbps in the downlink and 52.2 Mbps in the uplink. The theoretical maximum speed offered by an operator is more than 1.5 Gbps, assuming that backhaul or network resources are not a constraint. That maximum will be constrained by user handset capability. Premium handsets available in the Netherlands have a limit of 600 Mbps in the downlink and 100 Mbps in the uplink, therefore effectively capping the maximum users can experience. A typical user's device is more likely to be able to support speeds of 300 Mbps in the downlink and 75 Mbps in the uplink, so the subscriber with an average handset is likely to experience a maximum speed half that of a subscriber with a premium handset.

Downlink speeds experienced by subscribers at present

MNO	Minimum Mbps	Average Mbps	Maximum Mbps *(capped)*
All	4.1	58.7	600.0

Source: PA analysis

Uplink speeds experienced by subscribers at present

MNO	Minimum Mbps	Average Mbps	Maximum Mbps *(capped)*
All	0.7	52.2	100.0

Source: PA analysis

QUESTION 2: With respect to minimum service level:

a. **What can reasonably be required as a minimum service level for providing coverage in 98% of every municipality in the Netherlands two years after issuance of the 700 MHz licences (approximately H1 2022)? The minimum service level will be defined as a condition which can be attached to rights of use for the radio frequencies and can be enforced.**

b. **Given technological developments, what can reasonably be required as a minimum service level for providing coverage in 98% of every municipality in the Netherlands six years after issuance of the 700 MHz licenses (approximately H1 2026)? Also, this service level will be defined as a condition which can be attached to rights of use for the radio frequencies and can be enforced.**

c. **What average and maximum speeds can the majority of users expect under these two minimum service level requirements?**

The Ministry seeks to set a minimum service level allied with release of 700MHz spectrum. The suggestion is that MNOs can use not only 700MHz spectrum but any/all existing spectrum holdings to achieve that minimum. MNOs are most likely to use the 700 MHz band to achieve a desired 98% geographic coverage obligation by municipality.

PA has modelled the likely service levels (minimum, average and maximum) two years and six years after the intended auction date, meaning in 2022 and 2026 respectively, considering the stated technical strategies of the MNOs, as well as PA's view of what other technical advances will be implemented by then.

The tables below show the *minimum* speeds that we calculate will be achieved in 98% of the area of each municipality in 2022 and 2026 for both downlink and uplink, again with 95% probability. Setting the *minimum* service level in 2022 at 3.7 Mbps in the downlink, increasing to 4.7 Mbps in 2026, will support delivery of *average* speeds experienced by all users of all networks of 138 Mbps in 2022, increasing to almost 180 Mbps in 2026. These minimum service levels represent the lowest speeds experienced by a user of any mobile network rather than an average of the lowest across all MNOs. Modelled values for each of the specific MNO networks are detailed in the main report body.

The maximum reflects the highest speed that could be experienced by a user of any mobile network, assuming backhaul or network resources are not a constraint. The technical advances that we expect the networks to put in place over the next decade and the spectrum available in which to offer these services will support significantly higher theoretical maximum speeds. However, the maximum values are again constrained by what handsets available at that time can support. PA expects market-leading category 12 devices introduced in 2018 will be superseded by category 16 devices in 2022, and category 21 devices by 2026 (device categories as set out in the 3GPP standards and included at end of this study). This will constrain maximum downlink speeds to 1,000 Mbps in 2022, increasing to 1,400 Mbps by 2026.

Downlink speeds achievable in 98% of each municipality in 2022 and 2026 with 95% probability

Year	Minimum Mbps	Average Mbps	Maximum Mbps *(capped)*
2022	3.7	138.5	1,000
2026	4.7	179.5	1,400

Uplink speeds achievable in 98% of each municipality in 2022 and 2026 with 95% probability

Year	Minimum Mbps	Average Mbps	Maximum Mbps *(capped)*
2022	2.0	103.2	100
2026	2.5	133.6	310

Source: PA analysis

The minimum speeds achievable for 2022 and 2026 are defined by the worst performing operator in the worst municipality. They comprise calculated rather than aspirational performance. As such, MEZA can have confidence in these figures as an absolute and uncontentious performance floor.

However, this floor does not serve to incentivise MNOs for continual performance improvement. The Netherlands holds and seeks to maintain an enviable position as the leading European market for mobile service performance. PA advocates that MEZA considers implementing a minimum service level that encourages the worst performing MNO(s) to equalise the performance between municipalities as well as with other MNOs. The average minimum performance in 2022 and 2026 respectively, weighted by total subscriber traffic is 8Mbps and 10Mbps. This is an appropriate target at which to set a regulatory condition for minimum service speed.

QUESTION 3: What would be the immediate effects on the service provided by the three current license holders in case:

- **a. They retain their current amount of spectrum in the 2100 MHz band, but there will be a rearrangement of frequency channels among the license holders;**
- **b. They only regain 2x15 MHz in the 2100 MHz band;**
- **c. They only regain 2x10 MHz in the 2100 MHz band;**
- **d. They only regain 2x5 MHz in the 2100 MHz band;**
- **e. They regain no spectrum in the 2100 MHz band.**

Due to the nature of impact on services, we answer questions ‘a’ to ‘e’ under three different headings as follows:

- Re-ordering of frequencies
- Impact of spectrum loss on 3G services
- Impact of spectrum loss on 4G services.

Reordering of frequencies

A reorder of current allocations, whether the aggregate amount remains the same per MNO or not, would require MNOs to carry out changes to their networks that would lead to localised, temporary interruption. All MNOs are likely to have sufficiently modern equipment deployed out in the network such that frequency reallocation requires only software changes to reconfigure network infrastructure. Changes to network configurations would most likely occur at night at defined intervals over a period of weeks, with MNOs likely to manage reconfiguration in tranches, rolling across areas of the country. Such activities are a regular part of the spectrum reallocation process in all countries. The actual impact will not be known until the MNOs understand how their allocations will change. In general, however, where MNOs retain their current overall amount of 2100MHz spectrum but must shift frequencies, it will lead to only minor disruption that may not be noticeable for most users and does not impact service continuity.

Impact of spectrum loss on 3G services

If MNOs lose some of their existing spectrum allocations in the 2100 auction, the service they provide may be affected. The extent of impact depends on how the individual MNOs currently employ their 2100MHz allocation and how they expect to employ it in the future. All three of the incumbent MNOs use the 2100 MHz band to support both 3G and 4G services. At aggregate level, we have assumed that they allocate their 2x20 MHz of spectrum equally between 3G and 4G.

Broadly, we expect MNOs to accommodate the loss of 2x5MHz or 2x10MHz by reducing the amount of spectrum that they allocate to 3G services. The impact on 3G service is considered modest and is in any case mitigated by the stated intention of two of the three incumbent MNOs to close their 3G networks by 2022. However, there remains a risk that 3G users as well as 4G users without VoLTE-capable handsets, experience the following:

- Deterioration of service as the loss of spectrum reduces capacity on the 3G network; or

- Loss of coverage in some localised areas where some MNOs may have opted *not* to deploy 900 MHz networks. This previous option relates to historic GSM-R interference concerns in the 900MHz band, although PA believes this interference issue has been resolved – meaning that there is nothing to prevent MNOs extending 900MHz coverage extension in proximity to railways.

Impact of spectrum loss on 4G services

The loss of 2x5MHz or 2x10MHz of spectrum in the 2100 MHz band is unlikely to have an impact on 4G services as MNOs will naturally opt to prioritise 4G service delivery over 3G service, through commensurate apportionment of their remaining 2100 spectrum to 4G. However, the loss of 2x15MHz and 2x20MHz (2x20MHz representing the entirety of any MNO's spectrum in the 2100 MHz band) will have a negative impact on 4G service speeds. The loss of spectrum will not affect continuity of service, since all MNOs have deployed LTE in other bands in addition to the 2100 MHz band, and will continue to radiate LTE service in those other bands.

QUESTION 4: How much time would the current license holders reasonably require to remedy the loss of frequencies in the 2100 MHz band, as described in question 3, and specified per expected effect on the service as identified in answer to question 3, if the goal is to prevent issues with continuity of service to end-users.

Mitigation of impact of reordering frequencies

Reordering spectrum frequencies will lead to temporary interruptions to some users' services, where 2100 MHz spectrum is the only band in use in that area. These interruptions are likely to be in the order of minutes rather than hours as changes are executed – and at night when fewer users are active. In addition, there may be temporary degradation of service or even isolated loss of coverage for a period of weeks where reconfigured areas border other areas in which previous network configurations prevail, in order to avoid interference disrupting services. However, MNOs have experience of carrying out these changes and will work together in the normal way to minimise the impact on users.

Mitigation of impact on 3G services

The impact on services will affect few users, since the switch to 4G services has been so rapid in the Netherlands; this means that the number of 3G-only users is small and continues to rapidly decrease yet further.

MNOs can mitigate the remaining impact of a loss of spectrum used to support 3G services by continuing to drive user handset refresh with appropriately priced VoLTE-capable, LTE handsets and services. Those remaining 3G users may in fact not experience any degradation of service at all, if the volume of remaining 3G traffic declines in line with the potential reduction in spectrum available for 3G service delivery.

The loss of 3G coverage using 2100 MHz spectrum can be mitigated even further by MNO extension of 900 MHz 3G network coverage. The time required to extend 900MHz coverage depends on a range of site-specific factors, including:

- The availability of existing sites in the required locations (or indeed whether new sites are required at all);
- Whether there is space at the site to deploy additional infrastructure; and
- Whether additional antennas, backhaul or power is required.

PA estimates that addressing the 900 MHz coverage gap requires approximately 100 additional sites and that if existing sites could be used, this activity could take 5 months.

By identifying those subscribers likely to be affected by loss of coverage and providing information about prospective changes including a closing down of the 3G service, as well as targeting them with appropriate commercial incentives MNOs are able to mitigate the impact on subscribers and even avoid the need to invest in additional UMTS 900 MHz band equipment. Commercial incentives might comprise attractive LTE service packages, handset-upgrade subsidies, service credits. Such incentivisation is business as usual for an MNO.

Mitigation of impact on 4G services

MNOs can attempt to mitigate the impact of the loss of 2100 MHz spectrum on 4G service quality by deploying additional capacity in other bands they use for LTE. The impact of a loss of spectrum in the 2100 MHz band will not be felt equally across all MNOs; those that have invested more heavily in the 2100 MHz band will be affected commensurately more. Deployment of additional sectors to expand capacity and bring services up to the level prior to the loss of spectrum could take over a year, depending on the MNO and resourcing approach.

These mitigations can be carried out in parallel, and their durations differ between MNOs

The mitigations to the impacts of losing spectrum in the 2100 MHz band require the MNOs to carry out a similar set of activities. These activities can be planned prior to the spectrum auction. Further, it is important to note that the various activities can be carried out concurrently following spectrum reassignment, rather than consecutively. The maximum transition time is therefore determined by the activity with the longest duration. This will vary by MNO.

MNOs have control over how services are impacted

The degree of impact from such scenarios remains largely within the control of the MNO. The auction mechanism enables an MNO to reflect the relative importance of spectrum to its technology strategy in the price it is willing to pay for 2100 MHz spectrum, thereby minimising the risk that loss of spectrum in the 2100 MHz band will have an impact on services. If an MNO does lose spectrum in the 2100 MHz band, it further remains within that MNOs control how services are impacted:

- An MNO that holds 2x10 MHz or more of 2100 MHz spectrum can choose how it allocates that spectrum between 3G and 4G services, and consequently whether a service loses capacity, or loses coverage. It should choose an allocation that optimises value to its customers;
- An MNO that must reduce the amount of spectrum available to 4G services can mitigate the impact of this loss of spectrum by deploying additional capacity in other bands. It is up to the MNO to decide when it starts such deployment;
- An MNO that chooses to or must stop using 2100 MHz spectrum to support 3G services can extend coverage of its 900 MHz 3G network to prevent loss of 3G coverage. There may be gaps in 900 MHz coverage at present due to legacy interference concerns or deployment decisions. The timetable for addressing these gaps is within an MNO’s control;
- An MNO can choose how to incentivise the migration of 3G service users to 4G services. This includes notifying users that it will implement a hard stop to 3G services, giving users time to migrate to 4G services, and offering appropriately attractive service packages and handset subsidies. MNOs can avoid the situation whereby users are affected by interruption of UMTS services in the 2100 MHz band.

MNOs can therefore plan now to reduce the risk of loss of spectrum and mitigate the impact of any loss of spectrum in the 2100 MHz band, preventing service continuity and quality issues wherever possible, without waiting for the outcome of the auction to make these issues apparent.

CONTENTS

1 INTRODUCTION

This section presents background information to the issues that the Ministry is considering and PA's approach to responding to the questions it has posed.

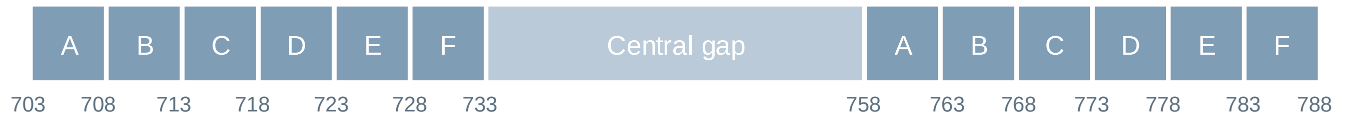
1.1 THE MINISTRY'S QUESTIONS

This section summarises the Ministry's proposed approach to managing the distribution of spectrum, and the issues it is interested in examining.

1.1.1 The Ministry intends to release 700 MHz spectrum at the same time as reallocating 2100 MHz spectrum

In line with other European countries, MEZA intends to release 700 MHz spectrum to support the rollout of 5G services and extend access to high speed broadband services outside of urban areas. MEZA is proposing to auction 2x30 MHz of spectrum in the 700 MHz band. The spectrum is likely to be packaged in 2x5 MHz blocks, as shown in Figure 1.

Figure 1: Assumed packaging of spectrum in the 700 MHz band



Source: PA analysis

MEZA also intends to release 40 MHz of 1400 MHz spectrum. The expiry of the 2100 MHz licences in December 2020 provides MEZA with the opportunity to carry out a multi-band auction of spectrum in three bands, with the aim of offering the incumbents additional spectrum to add to their existing portfolios, but also providing new entrants with potential for accessing sub-1 GHz spectrum critical to coverage and supra-2 GHz spectrum critical for capacity. MEZA's aim is to hold this auction by the end of 2019. To do so, it must publish auction regulations in mid-2019, which need to cover the approach to managing the transition of 2100 MHz spectrum from the current to the future holders of the spectrum.

The 3.4-3.8 GHz spectrum band is regarded as "the primary band suitable for the introduction of 5G services in Europe".[1] MEZA has yet to announce the timetable for making this spectrum available. In the absence of clarity over when this spectrum will become available, the advantages that this spectrum offers have not been considered as part of this study.

1.1.2 The Ministry is considering what service level it should put in place regarding the use of sub-1 GHz spectrum

MEZA is considering imposing a coverage obligation on MNOs that hold spectrum in more than one sub-1 GHz band. Sub-1 GHz spectrum has the most attractive propagation characteristics for MNOs looking to extend coverage. At present KPN and Vodafone have deployed LTE in the 800 MHz band. Tele2 has also deployed LTE in the 800 MHz band, and T-Mobile has deployed LTE in the 900 MHz band, alongside GSM and UMTS networks.

MEZA is proposing a coverage target of 98% of the area of each municipality in the country. MNOs will look to meet this obligation in the most cost-effective way. The 700 MHz band has a key role to play in this deployment. Being in a lower spectrum band, it offers more attractive propagation characteristics than the 800 and 900 MHz bands, and also offers MNOs the opportunity of extending their networks into 5G. 700 MHz has been designated by the Radio Spectrum Policy Group (RSPG) as one of the three bands, along with 3.4-3.8 GHz and 26 GHz bands, that will enable 5G in Europe. The RSPG considers that 5G will be deployed "particularly in the 700 MHz band, to enable nationwide and indoor coverage."[2] This will further encourage MNOs to roll out network infrastructure in the 700 MHz band to futureproof their deployments for 5G.

MEZA is interested in the service level it could put in place to support the 98% coverage obligation it proposes to require MNOs to meet if they hold spectrum in more than one sub-1 GHz spectrum band. It has therefore posed two questions:

[1] Strategic Roadmap Towards 5G for Europe, RSPG, 09/11/2016
[2] Strategic Roadmap Towards 5G for Europe: Opinion on spectrum-related aspects for next-generation wireless systems (5G)", Radio Spectrum Policy Group, 09/11/2016

QUESTION 1: What is the level of service quality (in terms of speed and capacity) that the current operators can offer throughout the country within their current spectrum portfolio?

QUESTION 2: With respect to minimum service level:

a. **What can reasonably be required as a minimum service level for providing coverage in 98% of every municipality in the Netherlands two years after issuance of the 700 MHz licences (approximately H1 2022)? The minimum service level will be defined as a condition which can be attached to rights of use for the radio frequencies and can be enforced.**

b. **Given technological developments, what can reasonably be required as a minimum service level for providing coverage in 98% of every municipality in the Netherlands six years after issuance of the 700 MHz licenses (approximately H1 2026)? Also, this service level will be defined as a condition which can be attached to rights of use for the radio frequencies and can be enforced.**

c. **What average and maximum speeds can the majority of users expect under these two minimum service level requirements?**

PA's response to these questions is set out in section 2.

1.1.3 The Ministry also wishes to understand the impact of changes to allocations of 2100 MHz spectrum

Table 1 shows the current allocations of spectrum in the 2100 MHz band, and the specific frequency ranges occupied by each MNO.

Table 1: Current allocation of 2100 MHz spectrum in the Netherlands

	Block 1		Block 2		Block 3		Block 4		Block 5		Block 6	
Operator	Vodafone		KPN		T-Mobile		KPN		Vodafone		T-Mobile	
Uplink MHz	1920.0	1934.9	1934.9	1939.7	1949.7	1959.7	1959.7	1964.7	1964.7	1969.7	1969.7	1980.0
Downlink MHz	2110.0	2124.9	2124.9	2139.7	2139.7	2149.7	2149.7	2154.7	2154.7	2159.7	2159.7	2170.0
Nominal bandwidth MHz	15		15		10		5		5		10	

Source: Agentschap Telecom

Each of the MNOs holds 2x20 MHz spectrum in the 2100 MHz band. These holdings are split between:

- A 2x15 MHz contiguous block and a single 2x5 MHz block in the case of Vodafone and KPN; and
- Two 2x10 MHz contiguous blocks in the case of T-Mobile.

As set out in

Table 16, KPN, T-Mobile and Vodafone have all refarmed this spectrum to deploy LTE as well as UMTS technology in the 2100 MHz band. PA has assumed that each MNO splits its spectrum holdings in the 2100 MHz band equally between UMTS and LTE operation such that:

- 2x10 MHz is allocated to LTE operation; and
- 2x10 MHz is allocated to UMTS operation.

MEZA intends to reassign 2100 MHz spectrum at the same time as it releases spectrum in the 700 MHz band, as well as spectrum in the 1400 MHz band. It is interested in understanding the impact on MNO services of changes to spectrum holdings. MEZA has asked:

QUESTION 3: What would be the immediate effects on the service provided by the three current license holders in case:

a. **They retain their current amount of spectrum in the 2100 MHz band, but there will be a rearrangement of frequency channels among the license holders;**

b. **They only regain 2x15 MHz in the 2100 MHz band;**

c. **They only regain 2x10 MHz in the 2100 MHz band;**

d. **They only regain 2x5 MHz in the 2100 MHz band;**

e. **They regain no spectrum in the 2100 MHz band.**

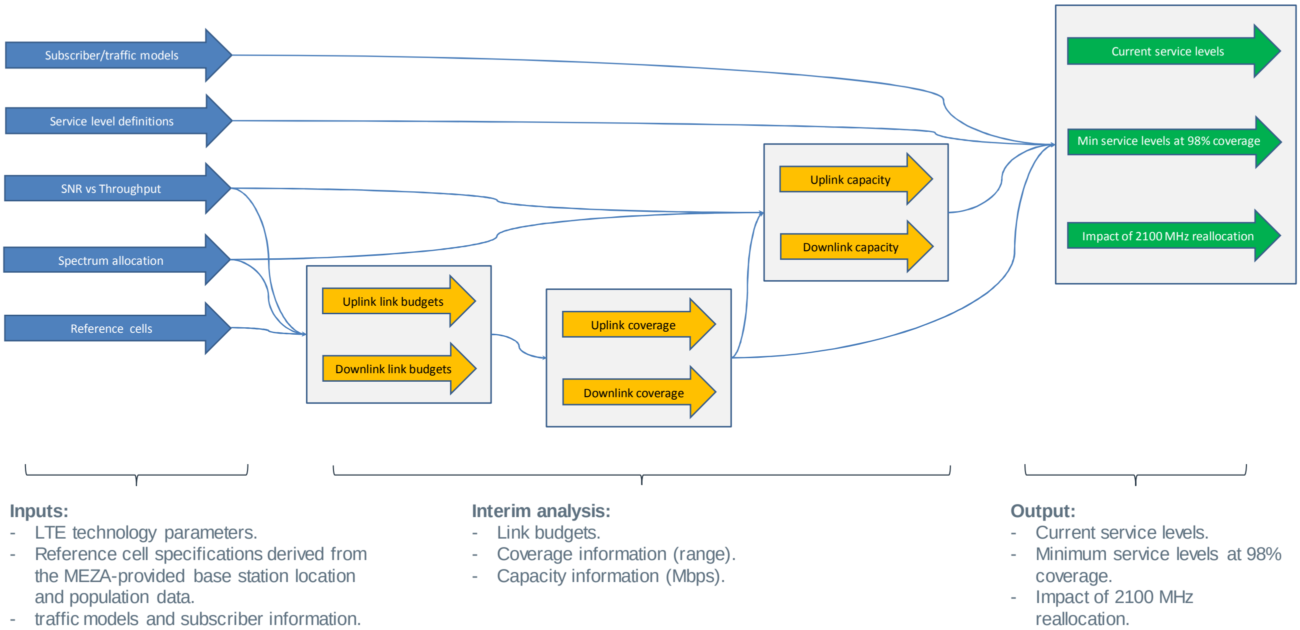
QUESTION 4: How much time would the current license holders reasonably require to remedy the loss of frequencies in the 2100 MHz band, as described in question 3, and specified per expected effect on the service as identified in answer to question 3, if the goal is to prevent issues with continuity of service to end-users.

PA's response to these questions is set out in section 3.

1.2 METHODOLOGY

PA has addressed the questions posed by MEZA through a combination of modelling and analysis of the market. PA has developed a model of the Netherlands mobile market that attempts to answer MEZA's questions. Figure 2 summarises the architecture of the model and summarises the inputs and outputs. Section 4 summarises the assumptions and input data used in the model in greater detail.

Figure 2: MEZA model architecture



Source: PA analysis

At the core of the model is a propagation model that employs COST 231/ Hata principles and accommodates the range of spectrum bands managed by the MNOs. We have used information about mobile sites contained in a database managed by Agentschap Telecom to derive inputs regarding the typical deployment characteristics of mobile networks in the Netherlands and understand how this varies by technology and geotype.

Section 2.2.3 summarises our views regarding technology development and how network deployment will change. These assumptions along with other inputs to the model have been informed by our work with mobile operators, network equipment vendors and handset manufacturers in developing and applying technology, as well as the views of the MNOs in the Netherlands.

The model incorporates inputs generated from analysis of geographic information about the Netherlands. This information has been provided to us in GIS form, and we have derived outputs from the GIS and used this information as the basis for the identification of typical geotypes and classification of municipalities into these geotypes.

We have developed a subscriber and traffic model for the Netherlands market that forecasts the volume of data traffic generated in the Netherlands and carried over each network technology developed by the MNOs. The data volumes are applied in the propagation model to understand the impact of user behaviour on the actual speeds users will experience when using mobile services in the Netherlands.

We have interrogated the model to highlight how the performance of the services provided to users changes under a range of scenarios, reflecting both the market today, and how we believe the market will develop in this time frames defined by MEZA. We have built on the outputs of the model to develop our analysis further, using inputs from experts within PA to fully respond to the questions posed by MEZA.

1.3 DEFINING A MINIMUM SERVICE LEVEL

Prior to answering MEZA's questions, PA has considered:

- How regulators around Europe have defined service levels associated with coverage for sub-1 GHz bands; and
- How MEZA should define a minimum service level to be associated with 98% coverage.

1.3.1 Regulators are enhancing service levels to align with aspirations for mobile broadband

Regulators have set coverage obligations and applied service levels to spectrum released in the sub-1 GHz bands released to the market in preparation for the widespread introduction of LTE and New Radio networks. Table 17 summarises information included in section 6 about the approaches taken in western Europe to setting coverage obligations and service levels for sub-1 GHz spectrum.

Almost all regulators have put in place coverage requirements that specify the percentage of population to be covered rather than the area. The exceptions are the regulators in:

- Denmark, Sweden and Portugal, where the regulators have specified requirements to deliver services to identified areas that are unserved or underserved by mobile broadband services; and
- The UK, where the regulator proposes to auction 700 MHz spectrum in 2019 with an obligation to cover 92% of the land mass of Great Britain. The associated service level is specified as a signal strength required to deliver a downlink speed of 2 Mbps in a lightly loaded cell with a 95% probability of success.

Ofcom's approach replicates the service level for the 800 MHz band auctioned in 2013 but applies a more stringent coverage requirement. This is a common theme, with regulators increasing the service levels in recent years to reflect technical advances. For example, in the six years between the 800 MHz spectrum and the 700 MHz spectrum being auctioned, regulators have made service levels more aggressive:

- In Belgium the required population coverage has increased from 98% to 99.8%, and minimum service level doubled from 3 to 6 Mbps; and
- In Sweden, the downlink speeds required have increased from 1 to 10 Mbps.

Regulators differ in the degree to which the service levels can be characterised as either network-centric, requiring the spectrum licence holder to deliver a network service that meets a specified minimum level, without consideration of the service provided to users, or user-centric, defining service levels in a way that requires the spectrum licence holder to deliver a specified minimum service to a user. Network-centric approaches include specifying:

- The technology that should be used in the spectrum. This is the approach used in east Asia and Singapore, where regulators have specified which IMT-Advanced technology should be deployed in the 700 MHz bands;
- The signal strength to be measured within a defined area; or
- The network speed to be measured for a user located at the base station.

User-centric approaches specify speeds that users will experience under defined circumstances:

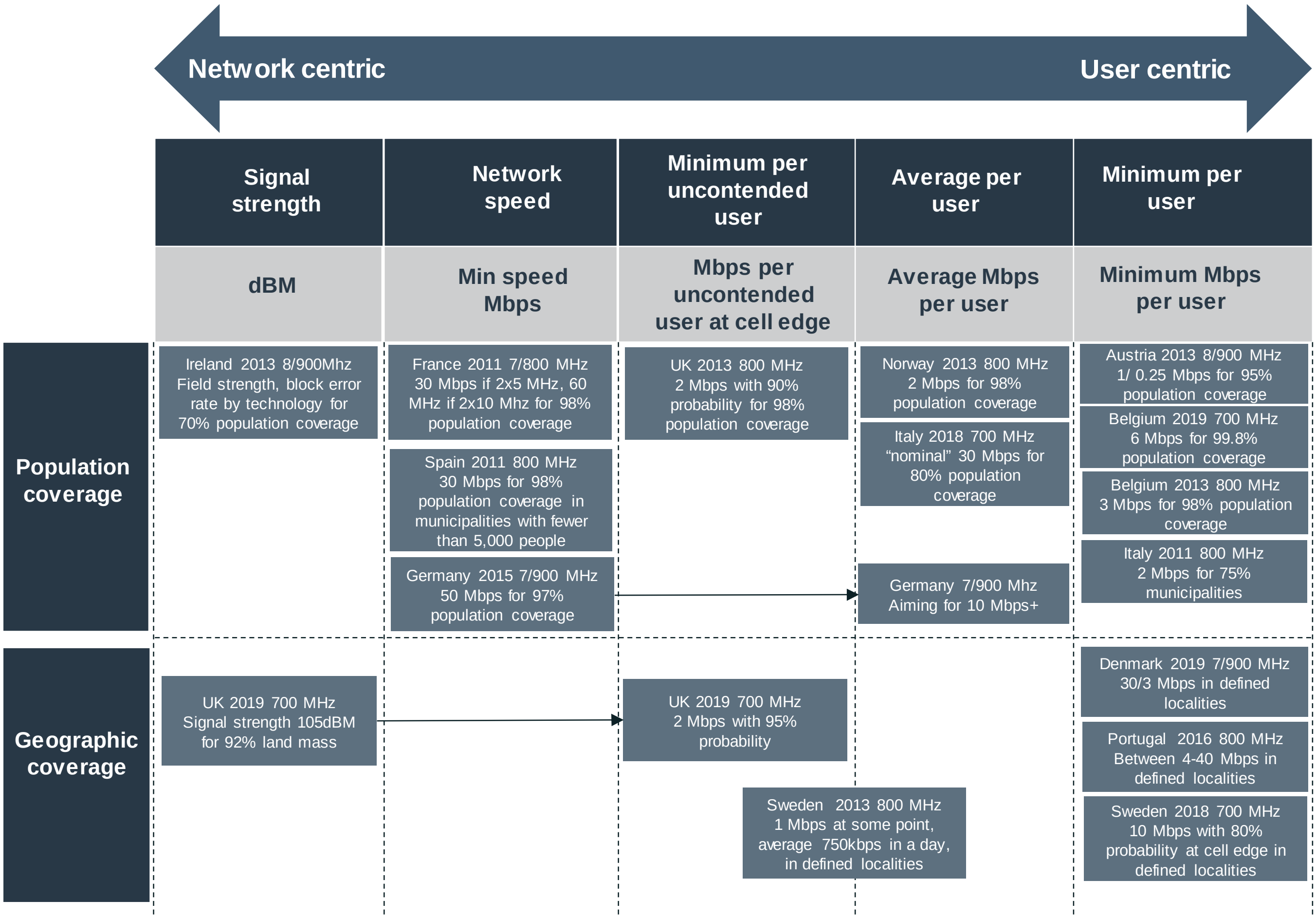
- A minimum cell edge speed in an uncontended cell, where a user is not competing with other users for network capacity. This is the approach pursued by Ofcom, although it proposes using a defined signal strength to deliver the minimum speed;
- A typical or average speed to be experienced by a user. This is explicitly required by the regulator in Norway, and implicitly in Italy, where the regulator requires this speed in name only, and in Germany where the BNA defines a network speed with the aim of giving each user 10 Mbps on average; or
- A minimum speed that a user should obtain. Where this approach has been taken it is applied either:
  - For a tightly defined area of the country where a regulator wants to improve network performance. This approach has been taken in Denmark, Portugal and Sweden; or
  - To support a population coverage obligation as in Austria, Belgium and Italy.

Figure 3 demonstrates the different approaches taken, and the locations of western European regulators on this continuum. Regulators propose measuring outdoor performance for these service levels, with the exception of Agcom in Italy, where the regulator requires holders of 700 MHz licences to deliver a "nominal" (interpreted as average) 30 Mbps to indoor locations covering 80% of the population.

Some regulators have incorporated a probability of obtaining the service level:

- Either explicitly as in Sweden where a 700 MHz licence holder will be required to provide coverage to defined underserved areas with an 80% probability of obtaining 10 Mbps at the cell edge, or France where Arcep requires licence holders to meet a requirement to provide a connection to users with 95% probability; or
- Implicitly, as in the UK, where Ofcom has defined a signal strength which it believes will deliver a minimum speed of 2 Mbps at the cell edge in an uncontended cell with a 95% probability of success.

Figure 3: Regulators have taken network or user-centric approaches to defining service levels associated with coverage obligations



Source: PA analysis

1.3.2 PA's proposes a minimum service level that specifies the probability of obtaining a minimum service level in each municipality

PA recognises that MEZA's aim for the service level to be associated with a geographic coverage obligation is to be able to set expectations amongst stakeholders regarding the services that will be available to users. This is a valuable aim, but one which needs to be balanced against other requirements for the service level:

- Planning to meet the performance measure – MNOs need to be able to plan to meet the performance measure in a way that minimises the risk of them failing to meet the performance measure and hence incurring any penalties that are included in the licence text.
- Measurement of performance – MNOs and the regulator need to be able to measure the actual performance of the network in a way that enables them to understand and agree whether specified performance is being met.

A minimum service level could be defined as:

- An absolute minimum service level, which every user will experience without exception;
- A minimum service level adapted by application of a probability of achieving the service level, meaning users will more likely than not achieve the defined minimum speed; and
- A minimum service level per uncontended user, reflecting an ideal where a user is not competing with others for network capacity, and has access to the maximum available bandwidth of the service.

Table 2 assesses these three user-centric approaches to specifying service levels against the three aims for the service level.

Table 2: Advantages and disadvantages of user-centric approaches to measurement of service levels

	Minimum service level per uncontended user	Minimum service level with probability	Absolute minimum service level
User specific	✓ User specific service level	✓ User specific service level	✓ User specific service level
User friendly	× Not easy to explain how this relates to service experienced by user × May lead to disillusionment as users would never experience the minimum	✓ Most users will experience better service, but some will experience worse service ✓ May set expectations in a way that means failures to achieve the minimum service level stand out even if not failing service level	✓ Easy for user to understand a guaranteed minimum ✓ Sets realistic expectations of a guaranteed minimum in the low kbps × An achievable minimum speed will be unimpressive, and will not reflect what most users' experience × May disillusion users and other stakeholders regarding network capabilities
Planning	✓ Easy for MNO to plan as not subject to circumstances outside of control of MNO, i.e. user volumes increasing or user behaviour changing	✓ Including probability makes it easier to plan and manage peaks × Remains subject to changes in user behaviour	✓ Easy to plan to achieve as defined minimum × No room for failure, which could occur when user behaviour diverges from predicted pattern
Measurement	✓ Can be tested through drive testing or crowd sourcing app × Definition of uncontended may be subject to dispute – unlikely a user could ever be uncontended × May be constrained by device capabilities	✓ Can be tested through drive testing or crowd sourcing app ✓ Easily replicable as user impact reduced through application of probability	✓ Can be tested through drive testing or crowd sourcing app ✓ Easily replicable in normal circumstances

Source: PA analysis

In summary using the minimum uncontended data rate attempts to rule out factors outside of an MNO's control from calculation of the minimum service level, and so may be more acceptable to the market. However, it is not an effective way of communicating the level of service users should expect to receive. It may also be difficult to agree on an approach to measuring performance in circumstances where few if any other users are competing for capacity.

Using an absolute minimum service level below which a user's experience may not fall under any circumstances provides clarity to users but defining an achievable level for MNOs means setting a service level so low it will mislead users and stakeholders regarding the capabilities of mobile services. Even at a low level, MNOs may believe it does not offer sufficient scope to absorb the impact of exceptional circumstances where the network is congested for reasons outside of the MNO's control.

PA's preferred approach is the application of a probability to a minimum service level. The use of probability may make it more acceptable to the market as it offers MNOs a margin of error in the event of circumstances arising that are outside of its planning horizon. It retains a user-friendly specification and sets expected performance at a level that most users will experience. PA therefore proposes that MEZA introduce a minimum service level with an associated probability.

Probability should be defined at a level that allows MEZA to set a minimum service level that is meaningful to users, and ensures users are very likely to receive the level of service specified, meaning their confidence in the minimum service level is enhanced. At the same time, it needs to be set at a level that enables the exclusion of outlying measurements that reflect circumstances that the network operator has not planned for and are experienced very occasionally by users.

Where other regulators have applied similar approaches, the measurement varies from:

- 80% in Sweden, where one 700 MHz licence holder has to meet a requirement to provide outdoor cell edge speeds of at least 10 Mbps with at least 80% probability “in normal conditions”;
- 90% for the UK’s 800 MHz licence, where Ofcom requires licence holders to cover an area containing 98% of the UK population, and provide a sustained downlink speed of 2MBps with 90% confidence when the network is lightly loaded; to
- 95% for the UK’s 700 MHz licence, where Ofcom has defined an acceptable user-facing service to be 2 Mbps available 95% of the time, and defined a signal strength that will deliver this level of service across 92% of the UK landmass.

PA believes that a MEZA should define a 95% probability of achieving the minimum service level. This will ensure that the minimum service level is relevant to users’ experience of broadband services, while providing them with sufficient confidence that a user-centric measure is being delivered. This aligns with Ofcom’s approach to defining an acceptable user-facing service level.

2 SERVICE QUALITY

This section addresses the questions posed by MEZA regarding the level of service quality that can be delivered at present and could be required of the MNOs following the award of 700MHz spectrum licences.

2.1 CURRENT SERVICE LEVELS

QUESTION 1: What is the level of service quality (in terms of speed and capacity) that the current operators can offer throughout the country within their current spectrum portfolio?

This section sets out PA's view of the minimum, average and maximum service levels that the MNOs can achieve in the Netherlands.

2.1.1 The minimum downlink speed experienced by users is 4.1 Mbps at present

PA has modelled the performance of the MNOs' networks using information about their current spectrum portfolios and assumptions about their technology strategies. Table 3 and Table 4 show the minimum and maximum experience, and the average experience weighted by traffic, across all MNOs. The minimum downlink and uplink speeds achieved across all MNOs are 4.1 Mbps and 0.7 Mbps respectively. The average speed across all MNOs is 58.7 Mbps in the downlink and 52.2 Mbps in the uplink.

The theoretical maximum downlink and uplink speeds are 1.5 Gbps and 1.2 Gbps respectively, although this will be limited by handset capabilities. PA assumes that a category 12 device represents a premium device that is available in the market now, and so defines the maximum speed that a user could experience. As shown in section 7, the maximum downlink and uplink speeds that a category 12 device can support are 600 Mbps and 100 Mbps respectively. This places a cap on the maximum service speeds a user can experience at present. This affects users of all MNOs. Based on the market shares of smartphones in use in the Netherlands at present, set out in Table 19, a typical user uses a category 5 handset. This places a limit of 300 Mbps and 75 Mbps respectively on the maximum downlink and uplink speeds that could be experienced by a typical user.

Table 3: Current minimum, average and maximum downlink speeds

MNO	Minimum Mbps	Average Mbps	Maximum Mbps
All	4.1	58.7	1,539.5

Source: PA analysis

Table 4: Current minimum, average and maximum uplink speeds

MNO	Minimum Mbps	Average Mbps	Maximum Mbps
All	0.7	52.2	1,199.8

Source: PA analysis

2.2 SERVICE LEVELS IN 2022 AND 2026

QUESTION 2: With respect to minimum service level:

a. **What can reasonably be required as a minimum service level for providing coverage in 98% of every municipality in the Netherlands two years after issuance of the 700 MHz licences (approximately H1 2022)? The minimum service level will be defined as a condition which can be attached to rights of use for the radio frequencies and can be enforced.**

b. **Given technological developments, what can reasonably be required as a minimum service level for providing coverage in 98% of every municipality in the Netherlands six years after issuance of the 700 MHz licenses (approximately H1 2026)? Also, this service level will be defined as a condition which can be attached to rights of use for the radio frequencies and can be enforced.**

c. **What average and maximum speeds can the majority of users expect under these two minimum service level requirements?**

This section sets out PA's view of:

- The minimum, average and maximum service levels that MEZA could require in 2022 and 2026 with 95% probability across 98% of the geographic area of each of the municipalities in the Netherlands;
- The technological developments that underpin the minimum service levels;
- The handset capabilities that cap the maximum service levels; and
- What these service levels mean for users of mobile services.

2.2.1 The minimum service level that all MNOs could achieve in 2022 is 3.7 Mbps in the downlink

Two years after the issuance of the 700 MHz licence in 2022, PA expects the MNOs to have deployed technical enhancements as set out in section 2.2.3, including:

- MIMO enhanced from 2x2 to 4x4 in the downlink; and
- QAM enhanced from 256 to 1024 nationwide.

We also assume that the amount of spectrum available to each MNO increases compared to the situation at present, with 2x10 MHz in the 700 MHz band available to each MNO. We expect the integration of the networks operated by T-Mobile and Tele2 to have been completed, with T-Mobile able to take advantage of Tele2's spectrum portfolio and deployed capacity.

Despite these enhancements, PA expects that all MNOs could achieve a minimum service level of 3.7 Mbps in the downlink with 95% probability in 98% of the area of each municipality in the Netherlands. This is a slight decline from the minimum service level achievable in 2018. This is a consequence of a bottleneck in suburban areas, affected by increases in demand which balance out expansion in capacity from technical advances.

The average downlink speed more than doubles, to 138.5 Mbps. The theoretical maximum downlink speed increases by three times to 4.2 Gbps. This is limited by handset capabilities, with premium handset capabilities likely to have reached 1 Gbps as set out in section 2.2.5.

The minimum, average and maximum service levels are summarised in Table 5 and Table 6 for downlink and uplink speeds respectively.

Table 5: Minimum, average and maximum downlink speeds experienced by users in 2022

MNO	Minimum Mbps	Average Mbps	Maximum Mbps
All	3.7	138.5	4,189.2

Source: PA analysis

Table 6: Minimum, average and maximum uplink speeds experienced by users in 2022

MNO	Minimum Mbps	Average Mbps	Maximum Mbps
All	2.0	103.2	3,062.1

Source: PA analysis

2.2.2 The minimum downlink service level achievable by all MNOs increases to 4.7 Mbps by 2026

By 2026, six years after the issuance of the 700 MHz licence, PA expects the minimum service level achievable with 95% probability in 98% of the area of each municipality in the Netherlands to have increased to 4.7 Mbps in the downlink and 2.5 Mbps in the uplink. The increase over the level in 2022 is a consequence of the imposition of technical enhancements set out in section 2.2.3, including the enhancement of MIMO from 4x4 to 8x8 in the downlink. The average downlink speed also increases, by 30% compared with 2022 to 179.5 Mbps, and the maximum theoretical downlink speed increases by 80% to 7.5 Gbps. Again, this will be constrained by the capabilities of the handsets in use in 2026, which are likely to limit the capability of an individual user to a maximum of around 1.4 Gbps.

PA's forecasts for service speeds in 2026 are summarised in Table 7 and Table 8 for downlink and uplink speeds respectively.

Table 7: Minimum, average and maximum downlink speeds experienced by users in 2026

MNO	Minimum Mbps	Average Mbps	Maximum Mbps
All	4.7	179.5	7,499.1

Source: PA analysis

Table 8: Minimum, average and maximum uplink speeds experienced by users in 2026

MNO	Minimum Mbps	Average Mbps	Maximum Mbps
All	2.5	133.6	5,481.6

Source: PA analysis

2.2.3 These forecasts incorporate technical advances that MNOs are likely to deploy

MNOs will define their technical strategies in response to technical advances in the standards, and how these are implemented by vendors in network solutions. LTE was originally specified in December 2008 by the 3GPP (Release 8). Since then there have been updates to the standards with each 3GPP Release, occurring approximately every 12-18 months, so that the latest specifications, Release 15, were frozen in June 2018. The two major uplifts to the LTE standards are LTE-Advanced, initially specified in 3GPP Release 10, and LTE-Advanced Pro, which was initially specified in 3GPP Release 13. In addition, 5G New Radio (NR) technology will be introduced during this period. PA has therefore focused on technology change that will affect services provided by MNOs in the Netherlands within the timescales defined by MEZA's questions.

Each MNO will have a technical strategy determined by its own understanding of how best to take advantage of technical innovations being introduced as well as the drivers of profitability of its existing business. PA has applied a generic technical strategy to each MNO.

Table 9: Assumptions regarding how MNO technical strategies will change

Area	Current position	Changes by 2022	Changes by 2026
Legacy networks and spectrum refarming	Three largest MNOs operate 2G, 3G and 4G networks Where two networks deployed in a band, the spectrum is split equally, or biased towards 4G	One legacy network switched off, 5G implemented Spectrum freed up by network switch off is refarmed for 4G	MNOs operate only 4G and 5G networks Spectrum freed up by network switch off is refarmed for 4G and 5G
Carrier Aggregation (CA)	Carrier aggregation deployed across all bands where LTE deployed	Carrier aggregation continues to be deployed across all bands where LTE and NR are deployed	Carrier aggregation continues to be deployed across all bands where LTE and NR are deployed
MIMO (Multiple Input Multiple Output)	2x2 deployed nationwide	4x4 downlink deployed nationwide	8x8 downlink deployed nationwide
QAM (Quadrature Amplitude Modulation)	256 QAM deployed nationwide	1024 QAM deployed nationwide	1024 QAM deployed nationwide
Availability of spectrum	As per MNO spectrum holdings	700 MHz spectrum distributed	NA
5G New Radio (NR)	Not deployed	Deployed in 700 MHz band	Deployed in the 700 MHz band

Source: PA assumptions

We have reflected the impact of these technical changes in the model used to provide some answers to MEZA's questions. Section 4 sets out how these enhancements are assumed to have an impact on network performance.

PA recognises that other the 3GPP releases enable further technical enhancements, such as relay nodes or enhancements to public safety capabilities. The impact of these enhancements has not been considered, either because there is a low probability of them being deployed in the Netherlands, or because they will not have a significant impact on the ability of MNOs to provide mobile broadband services.

2.2.4 The MNOs will also need to extend their networks to meet the 98% coverage target

These technological advances will allow the MNOs to extend the reach of their networks, and so contribute towards meeting MEZA's 98% coverage target. However, MNOs will still need to roll out additional sites. PA estimates that at least one MNO will need to roll out additional sites in 20 municipalities in total, although the number varies between MNOs. As a minimum an MNO is likely to need to deploy at least one additional site in a municipality, but the distribution of areas that are not covered may mean that more are required. Municipalities where the MNOs do not meet the coverage target are in suburban and urban areas. This number could be managed as part of business as usual activities.

2.2.5 Handset capabilities cap the maximum user experience

The ability of users to benefit from advances in network technology depends on the availability of compatible handsets. Section 7 shows the capabilities and maximum downlink and uplink speeds of the categories of handset that are defined in 3GPP specifications and their capabilities. These specifications define the maximum speeds that users will experience, depending on the category of device that is available, as summarised in This is summarised in Table 10.

- As set out in section 2.1.1, PA assumes a premium handset in the current operating environment is a category 12 device;
- By 2022, PA estimates a premium device will be a category 16 device, increasing the maximum speeds that users could experience to 1 Gbps in the downlink from 600 Mbps at present;
- By 2026 the capabilities of a handsets will have advanced further and a premium device may be best represented by a category 21 device, with a maximum downlink and uplink speed of 1.4 Gbps and 310 Mbps respectively.

Table 10: Assumed premium handset capabilities now, in 2022 and 2026

	Premium device 2018	Changes by 2022	Changes by 2026
Assumed category	12	16	21
Maximum downlink speed Mbps	600	1,000	1,400
Maximum uplink speed Mbps	100	100	310

Source: 3GPP

These device capabilities place an upper limit on the user experience, and the maximum speeds that can be measured as part of a testing regime.

2.2.6 What does this mean for users?

Table 11 and Table 12 summarise, for uplink and downlink respectively:

- The minimum service levels that MEZA could impose;
- The average speeds achievable; and
- The maximum speeds that users could experience capped by handset capabilities.

Table 11: Downlink speeds achievable in 98% of each municipality in 2022 and 2026 with 95% probability

Year	Minimum Mbps	Average Mbps	Maximum Mbps
2022	3.7	58.5	1000
2026	4.7	138.5	1400

Table 12: Uplink speeds achievable in 98% of each municipality in 2022 and 2026 with 95% probability

Year	Minimum Mbps	Average Mbps	Maximum Mbps
2022	2.0	103.2	100
2026	2.5	133.6	310

Source: PA analysis

These minimum speeds are capable of supporting voice, basic browsing, video calling, high quality music and video streaming, and gaming.

Average speeds available at present can support Ultra High Definition (UHD or 4K) video streaming. By 2022 the average user experience will be enhanced to high quality UHD services, and support 360 immersive Virtual Reality video services.

Premium handsets at present can support maximum speeds of 600 Mbps, capable of delivering services such as high-quality, immersive video experiences in virtual reality (6DoF or similar). By 2022 maximum speeds will be capable of supporting virtual reality gaming. However, until wireless networks can support speeds in excess of 200 Mbps consistently rather than in bursts, it is not practical to use these services supported solely by mobile networks.

2.2.7 MEZA should consider implementing a stretch target to address underperformance in specific municipalities

Sections 2.2.1 and 2.2.2 set out a minimum service level that all of the MNOs can achieve in every municipality in the country. This floor is 3.6 and 4.7 Mbps in 2022 and 2026 respectively.

This floor is defined by the worst performing operator in the worst municipality. Using the floor to define the minimum service level provides MEZA with confidence that speeds will not fall below this level. However this approach will not incentivise MNOs to improve performance. MEZA may therefore consider implementing a minimum service level that encourages the worst performing MNOs to equalise performance between municipalities, and also equalise performance between MNOs.

This target for underperforming MNOs could be defined by the average of minimum service levels weighted by the traffic carried by each of the MNOs. Using this approach would mean MEZA implements a minimum service level of 8 Mbps in 2022 and 10 Mbps in 2026. MNOs may need to invest to increase capacity to boost service speeds. PA’s view is that this investment requirement would be focused and not burdensome:

- A minimum service level based on a weighted average would only affect investment decisions in municipalities in the suburban geotype which did not meet the minimum service level;
- MNOs may be able to address the performance gap by lighting additional carriers on sites, rather than investing in new sites or base stations, minimising the capital investment required and the time required to meet the target.

3 CHANGES TO SPECTRUM HOLDINGS

This section addresses the questions posed by MEZA regarding the impact on MNOs of changes to spectrum holdings in the 2100 MHz band, and the timescales for mitigating the impact of these changes.

3.1 IMPACT OF CHANGES TO SPECTRUM HOLDINGS

QUESTION 3: What would be the immediate effects on the service provided by the three current license holders in case:

a. **They retain their current amount of spectrum in the 2100 MHz band, but there will be a rearrangement of frequency channels among the license holders;**

b. **They only regain 2x15 MHz in the 2100 MHz band;**

c. **They only regain 2x10 MHz in the 2100 MHz band;**

d. **They only regain 2x5 MHz in the 2100 MHz band;**

e. **They regain no spectrum in the 2100 MHz band.**

This section sets out PA's view regarding the impact of these scenarios on the services provided by the MNOs, including:

- The impact on LTE service quality of reducing the amount of spectrum available for LTE services;
- The impact on UMTS service quality of reducing the amount of spectrum available for UMTS services;
- Service disruption that may result from loss of UMTS coverage; and
- Service disruption that may result from reassignment of frequencies in the 2100 MHz band.

3.1.1 Reducing spectrum available for LTE services may adversely impact user experience

All three incumbent MNOs use the 2100 MHz band to provide LTE services. As all three operate UMTS networks in this band as well, the amount of spectrum used for LTE is assumed to be 2x10 MHz, rather than the full spectrum allocation. Any reduction in the amount of spectrum in the 2100 MHz from 2x20 MHz to 2x15 MHz or 2x10 MHz may not have an impact on LTE services as MNOs may prioritise the management of growing LTE traffic. Rather, the impact of reducing spectrum in the 2100 MHz band will only be felt:

- When MNOs reduce their spectrum deployed for LTE in the 2100 MHz band to 2x5 MHz; or
- When they are not able to obtain any spectrum in the 2100 MHz band.

The impact differs between the MNOs according to how much spectrum they hold in other bands, and how much LTE traffic they need to manage.

3.1.2 UMTS service quality may deteriorate because of the reduction in spectrum available

If MNOs prioritise the use of the 2100 MHz to manage the growth in LTE traffic, then UMTS service quality will deteriorate if:

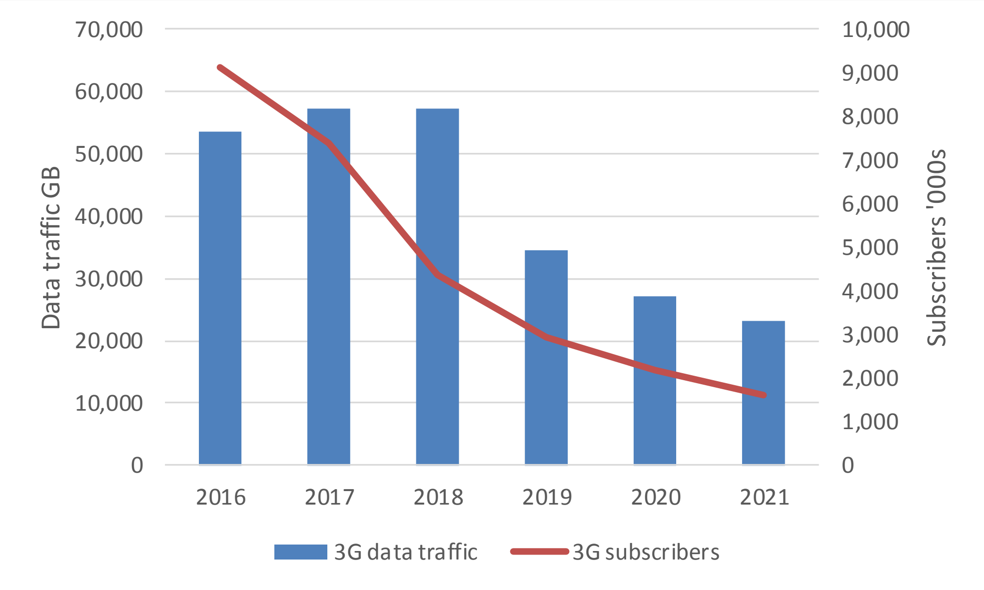
- The amount of spectrum allocated to UMTS is reduced to 2x5 MHz; or
- The amount of spectrum allocated to UMTS is reduced to zero. This could be the case under any scenario identified by MEZA.

Assuming Vodafone times the winding down of its UMTS network to be completed by the end of 2020, only KPN and T-Mobile would be affected by this change.

If the amount of spectrum in the 2100 MHz band allocated to UMTS is reduced to 2x5 MHz, there will be an impact on capacity available to UMTS service users, which may have an impact on service quality. This may be experienced as a reduction in data rates, or an increase in the number of dropped calls, during times of the day when the network is congested. If the amount of spectrum allocated in the 2100 MHz band was reduced to zero, this may lead to an increase in capacity issues.

However, the impact would be fall on an increasingly small number of subscribers. PA forecasts the number of UMTS subscribers will decline from almost 7.5 million in 2017 to just over 1.5 million in 2021 as the rapid take-up of 4G services continues. The amount of traffic generated by these users would also decline by over half over the same period. Therefore, users may not notice the impact of this reduction in available spectrum unless only 2x5 MHz in the 900 MHz band is available to them.

Figure 4: The number of UMTS subscribers is forecast to decrease to less than 2 million by 2021



Source: PA analysis

3.1.3 Some UMTS users may experience service disruption if spectrum in the 2100 MHz band is not made available for UMTS

If an MNO chooses not to or is not able to use 2100 MHz band spectrum to support UMTS services, there may be localised coverage issues. This could result in disruption for those users relying on UMTS coverage to provide services. These issues are a consequence of:

- The potential for interference between GSM-R networks and UMTS networks in the 900 MHz band; and
- Repeaters in an MNO's network supporting only UMTS connectivity in the 2100 MHz band.

GSM-R operates in 2x4 MHz blocks in the 876–880 MHz and 921–925 MHz bands. The possibility of interference between GSM-R services and UMTS in the 900 MHz band has been raised in the past, with train operators in the Netherlands expecting interference to be a consequence of "blocking and intermodulation occurring in the receivers of the train radios. Also, interference from out of band emissions is expected."[3] This meant MNOs were unable, or willing to forego the opportunity, to roll out UMTS in the 900 MHz band to minimise the risk of interference.

In addition, UMTS coverage may have been extended within buildings or tunnels using 2100 MHz repeaters which do not operate in another band. An MNO may therefore have to switch out equipment to ensure UMTS in the 900 MHz band is available. This issue is unlikely to affect many locations. However, these repeaters may be shared by multiple MNOs and managed by a competitor or a third party, increasing the complexity of replacement.

UMTS devices sold in the Netherlands through MNOs' retail channels and mainstream retailers will operate in all 3GPP bands including both 900 and 2100 MHz bands. If UMTS networks were not able to operate in the 2100 MHz band, then handsets will be able to connect to the UMTS 900 MHz network. There may be a small number of devices, both handsets and repeaters, that have been imported into the Netherlands that use 2100 MHz for UMTS but not 900 MHz. These subscribers would use SIM-only 3G services. Subscribers using these devices would lose service should their MNO lose all spectrum in the 2100 MHz band. It is not possible to estimate the number of these users, but it is likely to be small.

3G voice traffic is generated by 4G users as well as 4G users. The MNOs in the Netherlands introduced Voice over LTE (VoLTE) in their networks in 2016 in the case of KPN, Vodafone and Tele2[4], and 2017 in the case of T-Mobile.[5] Prior to those dates, subscribers used the GSM and UMTS networks to carry voice traffic. There will remain users whose LTE devices do not support VoLTE, and therefore depend on the UMTS network for voice communications. These users may not be able to access voice services in areas without UMTS coverage.

[3] "GSM-R Interferences – Contributions from delegations and ERA on issues, statistics and best practices as a follow-up to the discussion in RSC#42", Radio Spectrum Committee, RSCOM13-10, 26/02/2013
[4] https://www.telegeography.com/products/commsupdate/articles/2016/12/20/tele2-nl-customers-provided-with-volte/
[5] "The 2018 Mobile Network Test in the Netherlands", P3

3.1.4 Network reconfiguration will cause minor, temporary degradation of services

The incumbent MNOs are highly likely to hold different allocations of spectrum if they retain 2x20 MHz, and potentially different quantities of 2100 MHz spectrum, following completion of the auction. Consequently, the MNOs will need to undertake a national frequency re-planning exercise.

The MNOs are likely to operate modern networks with software configurable line cards in base stations. As these line cards are remotely configurable, changes to base stations equipment can be carried out from the MNO's Network Operations Centre, without the need for site visits. The execution of these changes in the network will however lead to temporary interruption of services from that site. Remote changes can be executed in the middle of the night. The interruptions should happen overnight, and last 1-2 hours.

There may be areas of contention between MNOs, particularly at the borders between areas where changes have been carried out and areas where changes have yet to be carried out. There may be a need for MNOs to agree a temporary moratorium on use of a frequency in border areas to avoid causing interference. These issues will be resolved once all areas have transitioned, although this may take up to 4 months as set out in section 3.2.1.

MNOs may also need to change carrier-specific Radio Frequency (RF) filters at sites. MNOs have deployed RF filtering equipment at sites shared with other MNOs, or sites in close proximity to each other. If the frequencies deployed change, then the filtering will need to be reconfigured to align with the changed frequency arrangements. However, the outcome of the auction is likely to result in each MNO being allocated contiguous blocks of spectrum, meaning the need for filtering equipment will be reduced compared to the current situation where each MNO manages multiple non-contiguous blocks. The number of sites affected is likely to be small. Most sites will have base band filtering in place, and any interference between MNOs is likely to be manageable. However, there may be a small number of sites which still require a visit for manual configuration. PA estimates the number of these sites to be limited to about 2% of the total, or around 100 for each MNO. These changes will require a site to be switched off temporarily.

The impact of these changes is hard to define. In urban and suburban areas users may only experience a minor degradation of service as adjacent cells are available using alternative spectrum bands. In rural areas, where around a third of cells are located, there may be a loss of coverage if no alternatives using other spectrum bands are available. In areas where an MNO uses 2100 MHz only to provide services there is a range of impacts:

- Configuration changes that are managed remotely will be localised and temporary, limited to 1-2 hours, and happen overnight;
- Changes that require visits to sites change physical changes to equipment installed on towers, such as antennas, will have to be carried out during daylight hours, thereby increasing the impact on users, and longer, perhaps 2-3 hours in length;
- A temporary moratorium on use of a frequency may cause a loss of service that may last between 1-2 weeks, or up to 3 weeks.

3.2 MITIGATING THE IMPACT OF CHANGES TO SPECTRUM HOLDINGS

QUESTION 4: How much time would the current license holders reasonably require to remedy the loss of frequencies in the 2100 MHz band, as described in question 3, and specified per expected effect on the service as identified in answer to question 3, if the goal is to prevent issues with continuity of service to end-users.

This section sets how MNOs could mitigate the impact of reassignment or loss of spectrum in the 2100 MHz band identified in section 3.1, and the timescales for implementing these remedies, including how MNOs can:

- Carry out changes to network configuration to implement reassignment of spectrum;
- Address deterioration in LTE service quality; and
- Address loss of UMTS coverage resulting from loss of 2100 MHz spectrum.

Only the first of these mitigations is an inevitable consequence of the reassignment of spectrum. It remains within the control of the MNOs when the other mitigations are implemented, meaning users may not experience any impact as a consequence of the loss of spectrum in the 2100 MHz band.

3.2.1 MNOs need to work together to minimise disruption from reassignment of spectrum, whatever the outcome of the auction

As set out in section 3.1.4, MNOs will need to coordinate amongst themselves and with their counterparts across borders in Belgium and Germany to reconfigure their networks in response to changes in spectrum allocations. The MNOs will then work together to identify and address interference issues that may arise from these plans and adapt their plans accordingly. Reconfiguration will lead to localised, temporary and short-term degradation of service. Loss of service is likely to be limited to a handful of remote locations where 2100 MHz is the only band used to support services, and MNOs agree to a moratorium on use of frequencies to prevent interference issues.

The auction process could be used to support this process by enabling MNOs to express preferences for specific frequencies. This may mean the changes to configuration and filtering would be minimised. However with all MNOs holding non-contiguous blocks of spectrum in the 2100 MHz band at present, and the result of the reassignment likely to result in the allocation of contiguous blocks, each MNO will need to make changes to the configuration of its network.

These impacts can be mitigated by minimising the time taken for all MNOs to reconfigure their networks. Each MNO would need to carry out the activities set out in Table 13, which also sets out our assumptions regarding the time taken to complete these activities.

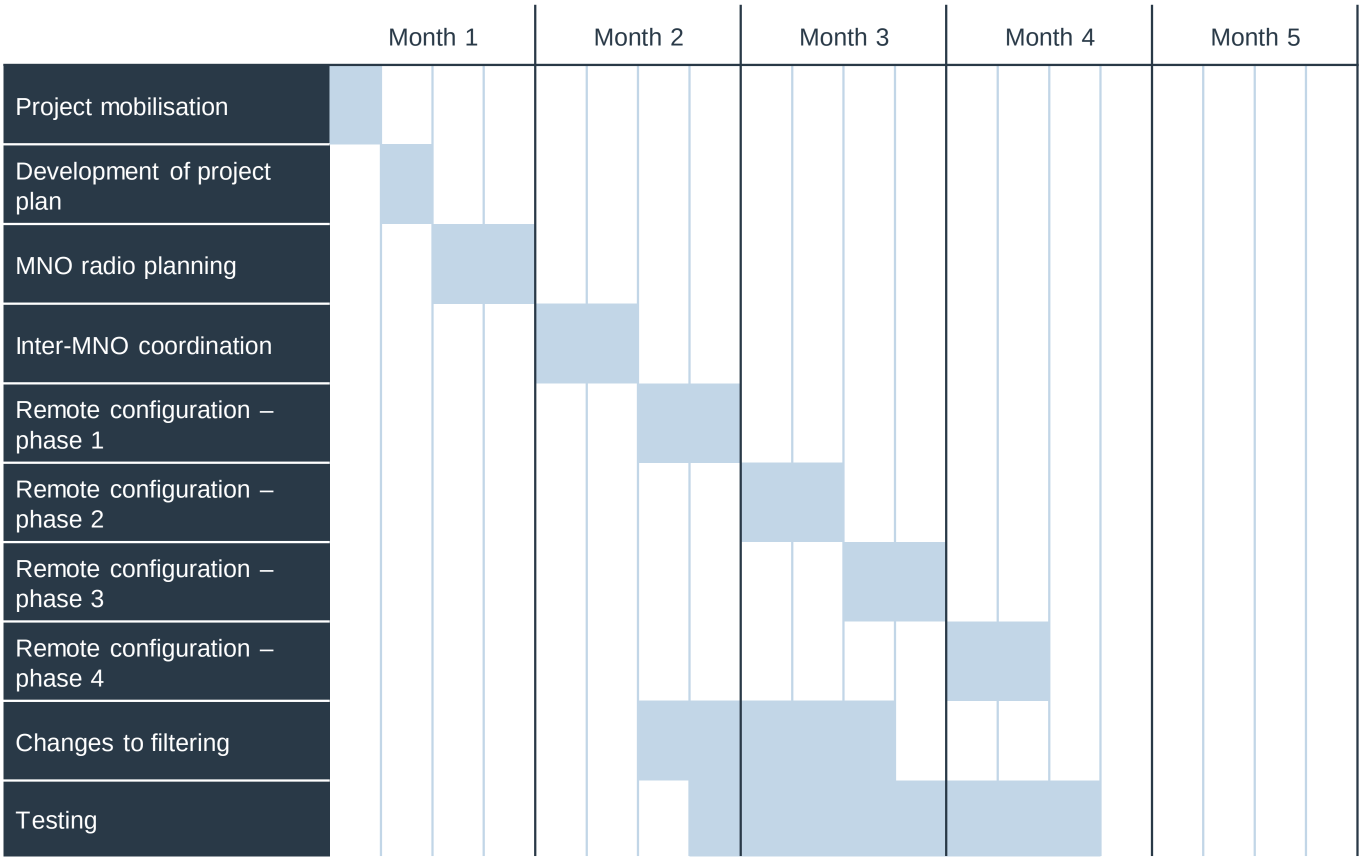
Table 13: Assumptions regarding duration of activities required to carry out network configuration

Activity	Assumption	Duration
Project mobilisation	Period required to identify resources required to start project, including personnel, tools, equipment both internal to MNO and from external third parties	1 week – this is an activity that all MNOs have carried out repeatedly, and is an extension of business as usual, therefore there is no extensive period of mobilisation required
Development of project plan	Development of plan, and ongoing management of project to carry out changes, in coordination with other MNOs	1 week – activity frequently carried out by MNOs
MNO radio planning	Exercise carried out by MNO to develop radio plan for our sites	2 weeks
Cross-MNO coordination	Working with other MNOs to coordinate planning with the aim of minimising interference	2 weeks
Remote configuration	Execution of remote changes to the network, assumed to be carried out in four phases, each phase lasting two weeks to allow for packaging up and testing of release, execution of change in a defined geography	4 x 2 weeks for each phase
Changes to filtering	Visits to 100 sites to carry out physical changes to filtering equipment. Estimated 100 sites require visits, and that a team of 2 can carry out 2 changes a day. Assume 2 teams deployed.	5 weeks
Testing	Carried out in parallel to execution of remote configuration and changes to filtering	1 week following final changes

Source: PA analysis

MNOs will need to carry out these activities following a shift in frequencies held under any scenario. Therefore, these activities and the potential duration will apply under any of the scenarios outlined by MEZA. The duration of these activities depends on the availability of resources to carry out these activities, and therefore the budget that the MNO is willing to allocate to the redeployment project. However, with adequate resources applied, and no interruptions to execution, these tasks can be completed according to the plan set out in Figure 5, in under 4 months.

Figure 5: Project plan for installation of execution of changes to configuration and filtering



Source: PA analysis

3.2.2 MNOs can address a reduction in capacity by deploying additional infrastructure

A loss of spectrum in the 2100 MHz band will lead to a reduction in service quality offered by the MNOs as set out in section 3.1.1. This loss of spectrum will not have an impact on service continuity, and therefore MNOs can respond to a reduction in service levels caused by loss of 2100 MHz by deploying additional capacity in other bands to enhance performance of their networks. There is a range of options available to MNOs regarding how they would go about expanding capacity, including carrying out the activities set out in Table 14. This table also sets out our assumptions regarding the time taken to complete these activities.

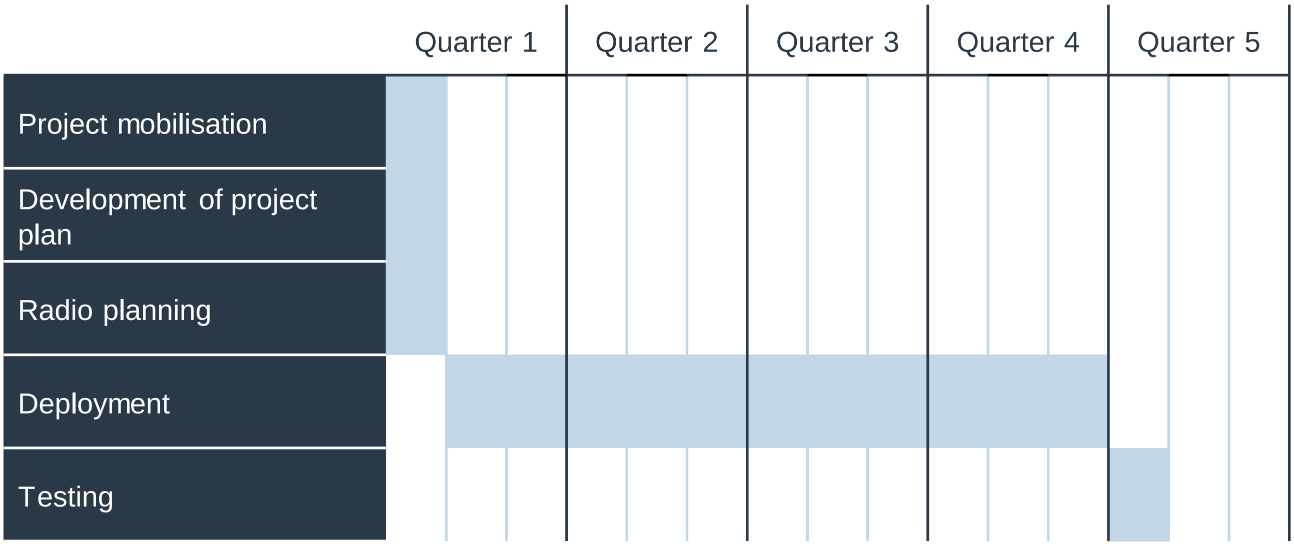
Table 14: Assumptions regarding duration of activities required to deploy additional sectors and sites

Activity	Assumption	Duration
Project mobilisation	Period required to identify resources required to start project, including personnel, tools, equipment both internal to MNO and from external third parties	2 weeks
Development of project plan	Development of plan, and ongoing management of project to carry out changes at sites	2 weeks
Radio planning	Exercise carried out by MNO to develop radio plan for our sites to ensure sufficient capacity is deployed	4 weeks
Deployment activities	Visits to some thousands of sites to carry out installation of additional sectors.	10-11 months depending on scenario
Testing	Carried out in parallel to execution of remote configuration and changes to filtering	Carried out in parallel to execution of changes

Source: PA analysis

The duration of these activities depends on the availability of resources to carry out these activities, and therefore the budget that the MNO is willing to allocate to the redeployment project. However, with adequate resources applied, and no interruptions to execution, these tasks can be completed according to the plan set out in Figure 6 in over a year.

Figure 6: Project plan for installation of additional sectors



Source: PA analysis

The need for additional sectors may have knock on impacts depending on:

- The type of tower available. A tower supporting an omni-sector base station is likely to be a monopole that could not support a tri-sector base station;
- The space available on the tower, and whether the wind loading would allow additional sectors to be installed;
- The space at the site, and whether there was sufficient space to enhance power or active equipment at the site;
- The backhaul used at a site, which may need to be upgraded to manage additional traffic. There may be a need to add microwave dishes at the site, which means the type of tower, the space on the tower, the wind loading, and the conditions of use may need to be considered.

Therefore, the need to deploy additional sectors may lead to the need to deploy further sites. The time taken to deploy an additional site is uncertain and subject to significant variation. For new greenfield sites, this may require identification of a suitable site, agreement with a landlord and potentially approval from planning authorities. The time taken to deploy a new site may therefore vary from 3 months to a year or more, possibly extending a project to mitigate the impact of loss of 2100 MHz spectrum. However we have assumed that all additional sectors can be deployed on existing sites.

3.2.3 Loss of UMTS coverage using 2100 MHz can be mitigated by deploying additional UMTS coverage in the 900 MHz band

As set out in section 3.1.3, UMTS users may experience localised loss of coverage if, following the reassignment of 2100 MHz spectrum, an MNO relies on the 900 MHz band only to support UMTS users, and the footprint of the 900 MHz network does not match the footprint of the network using the 2100 MHz band.

The decision to install equipment supporting 2100 MHz only may have been taken because of the risk of interference with other networks, particularly the GSM-R network operated by the railway operators in the Netherlands. However, interference issues have been examined and found to be manageable. ECC reports that UMTS can co-exist with GSM-R in the 900 MHz band:[6]

- Provided there is a carrier separation of 2.8 MHz or more between a UMTS 900 carrier and a GSM-R carrier. This should be the case for all carriers except the those in the 880-885 MHz band operated by Vodafone;
- Except in specific circumstances up to 4km from the track where coordination is required when filtering or engineering measures should be applied.

This conclusion appears to be supported by MNOs that have installed base stations in close proximity to railways and stations. There are base stations opposite Hardinxveld-Giessendam railway station, for example, with the direction of radiation crossing the tracks. This suggests that interference issues can be resolved and that gaps in coverage caused by the loss of 2100 MHz spectrum can be mitigated by the extension of coverage using UMTS in the 900 MHz band.

PA assumes that up to 100 sites supporting UMTS in the 900 MHz band would be required to address this shortfall in coverage. It is likely that these sites could be installed on existing sites operated by the MNO, as the denser

[6] “Compatibility between UMTS 900/1800 and systems operating in adjacent bands”, ECC Report 96, March 2007

arrangement of sites required for a network using 2100 MHz spectrum would provide an MNO with the number of sites required to support a network using the 900 MHz band.

In addition, there may be small cells or repeaters that use 2100 MHz spectrum only which would not be able to provide coverage if an MNO does not or cannot use 2100 MHz to support UMTS. In this instance, the MNO would need to install a replacement that supported communications in the 900 MHz band. PA assumes that there are under 50 locations where this change would be required.

In both these circumstances the MNO would need to carry out the activities set out in Table 15, which also sets out our assumptions regarding the time taken to complete these activities.

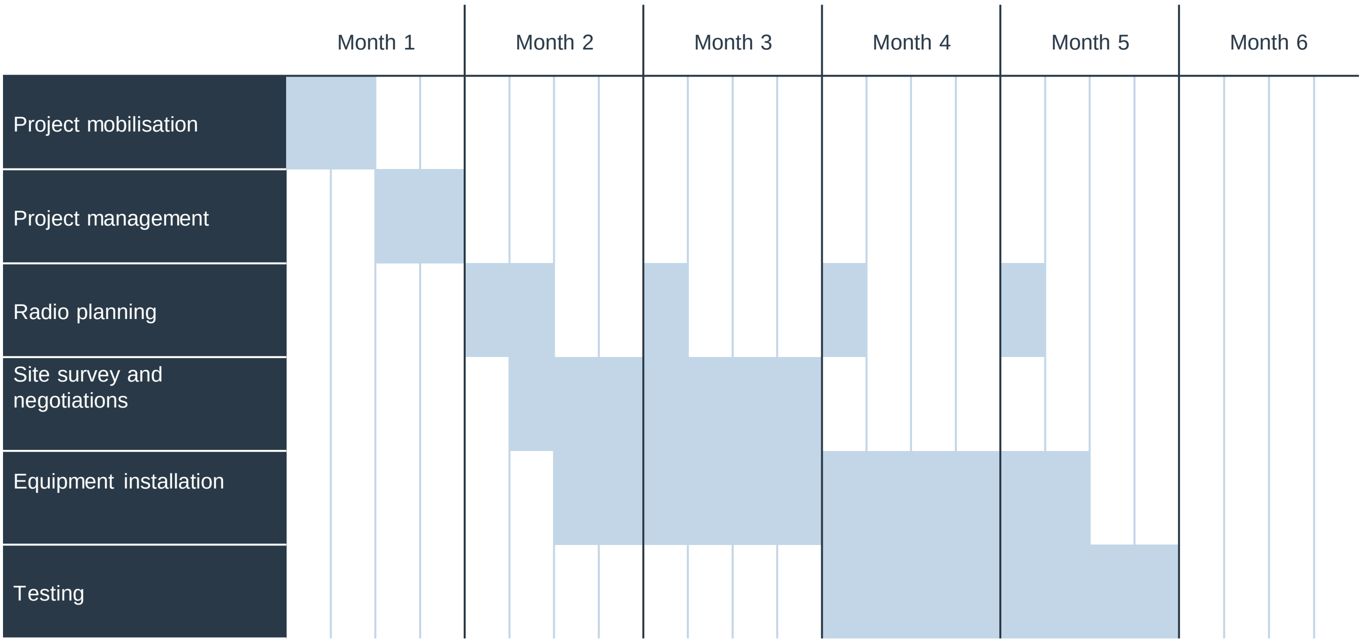
Table 15: Assumptions regarding duration of activities required to carry out 900 MHz UMTS implementation

Activity	Assumption	Duration
Project mobilisation	Period required to identify resources required to start project, including personnel, tools, equipment both internal to MNO and from external third parties	Two-week mobilisation period to secure initial resources required to start programme
Development of project plan and ongoing project management	Development of plan, and ongoing management of project to carry out installations, coordinating radio planning, design, deployment and testing of equipment at sites	Two-week period to develop plan, followed by ongoing tracking and management of execution
Carry out radio planning	Carried out as a single exercise up front, to identify the sites that would require installation with 900 MHz equipment. May require rework as availability of sites changes over time	Two-week period at the beginning of a project, plus occasional involvement on an ongoing basis when required
Carry out site survey and negotiate with landlord prior to installation	Assume that not all base station sites would need to be considered – only 50% of the 100 base stations would need to be addressed, but all 50 repeater sites Assume all repeater sites would need to be visited/ landlords would require negotiation	Can be carried out in parallel with installations at sites which do not require surveys or negotiations with landlords, and therefore should not be on critical path. However, there is a risk that landlord permissions are not forthcoming or commercial arrangements are not sufficiently attractive on a small number of sites to secure agreement, meaning delays are introduced
Install equipment at the site	Each site requires a team of two to replace equipment: • Two repeater sites could be handled each day • One base station site could be managed in a day.	In total the replacement of equipment would take 125 man days of effort. With two teams working on the project, the elapsed time for carrying out this activity could be completed in 12 weeks
Test and commission equipment	Ongoing activity following installation of equipment at site, but can only be completed following installation of equipment at final site	Follows completion of installation of equipment by two weeks

Source: PA analysis

The duration of these activities depends on the availability of resources to carry out these activities, and therefore the budget that the MNO is willing to allocate to the redeployment project. However, with adequate resources applied, and no interruptions to execution, these tasks can be completed according to the plan set out in Figure 7.

Figure 7: Project plan for installation of equipment to enhance 900 MHz UMTS coverage



Source: PA analysis

The overall elapsed time within which this mitigation could be completed is therefore estimated to be 5 months, but activities dependent on third parties such as striking agreements with landlords could extend this time period.

There may be issues at existing sites regarding tower type, wind loading, space or conditions of use, as described in section 3.2.2, that prevent a 900 MHz cell being installed at the site. This means additional sites would need to be implemented to enable 900 MHz coverage to be extended. The timescales for identification and implementation of new sites are subject to multiple factors, and could vary from 3 months to 1 year or more. This may extend the timetable for deployment.

3.2.4 These activities could be carried out in parallel

The mitigations to the impacts of losing spectrum in the 2100 MHz band may be different, but they require the MNOs to carry out similar tasks:

- Mobilising to carry out a project;
- Carrying out a network planning activity;
- Making changes to the network, either remotely or by visiting sites; and
- Testing the outcome of the changes.

These activities can be carried out in parallel following reassignment of the spectrum. The maximum transition time is therefore determined by the activity with the longest duration, but this will vary by MNO.

3.2.5 MNOs can prevent loss of service by ensuring users have access to alternative frequencies and technologies

Service interruptions caused by a loss of 2100 MHz UMTS coverage, either temporary as networks are reconfigured following reassignment of spectrum or permanent if the UMTS network is closed down, are likely to be localised. The number of users affected because they are fully or partially dependent on 3G services, will be small. While MNOs could remedy the coverage gap by enhancing 900 MHz UMTS coverage, it may be timelier and in the longer term more appropriate, to further encourage the migration away from 3G services - a migration that is happening comparatively rapidly in any case in the Netherlands. This would resolve the issue of service interruptions before they occur.

MNOs can deploy strategies to address the specific circumstances arising out of the 2100 MHz auction:

- Identifying those geographies and customer segments that are most likely to be affected by loss of 2100 MHz 3G services;
- Making those subscribers aware that there is a risk they may be affected by a loss of service following loss of 2100 MHz spectrum for UMTS;
- Offering various commercial incentives such as handset subsidy, which enable users with 3G-only or non-VoLTE handsets to take advantage of LTE services in the 1800 or 2600 MHz bands.

3.2.6 It is within the control of MNOs to address most of the risks to service caused by loss of spectrum in the 2100 MHz band

The impact of a loss of spectrum in the 2100 MHz band will not be felt equally. Services provided by MNOs that have invested significantly in the 2100 MHz band will be affected more by loss of spectrum than those provided by MNOs that have focused investment in other bands. The auction mechanism provides MNOs that have invested more in the 2100 MHz band with the ability to show that they place a greater value on this spectrum than MNOs whose focus has been on bands. MNOs are therefore able to use the auction process to minimise the risk of loss of spectrum that is more valuable to them than to other MNOs.

If an MNO does stand to lose spectrum in the 2100 MHz band, the impact of this remains under the control of the MNO:

- An MNO that holds 2x10 MHz or more of 2100 MHz spectrum can choose how it allocates that spectrum between UMTS and LTE services, and consequently whether a service loses capacity or loses coverage. It should choose an allocation that optimises value to its customers;
- An MNO that must reduce the amount of spectrum available to LTE services can mitigate the impact of a loss of spectrum by deploying additional capacity in other bands. It is up to the MNO to decide a timetable for when and how this deployment commences;
- An MNO that either chooses to or must stop using the 2100 MHz spectrum to support 3G services can extend 3G coverage of its 900 MHz UMTS network to compensate. There may be gaps in national 900 MHz UMTS coverage at present due to legacy interference concerns or other commercial deployment decisions. Should an MNO wish to de-risk the potential impact on its customers of losing spectrum in the 2100 MHz band, it can consider augmenting UMTS service in the 900 MHz band now. The timetable for addressing such gaps is within an MNO's control;
- An MNO can choose how to incentivise the migration of UMTS users to LTE service. This includes notifying users that it will implement a hard stop to 3G services, giving those users time to migrate to LTE services, and offering appropriate commercial incentives such loyalty/service credits, attractive upgrade service packages, handset subsidies and the like. Driving subscriber behaviour in this way is business as usual for an MNO.

Therefore, MNOs can plan now to reduce the risk of loss of spectrum and mitigate the impact of any loss of spectrum in the 2100 MHz band, preventing service continuity issues wherever possible, without waiting for the outcome of the auction to make these issues apparent. Alternatively, MNOs have the choice to wait until the auction has been completed and understand whether they have sufficient spectrum to maintain a UMTS network in the 2100 MHz band before determining its strategy, but run the risk of not being able to provide a service to UMTS subscribers, and offering a deteriorating quality of service to its LTE subscribers.

MNOs do not have a choice regarding the timing of making changes to the configuration and filtering deployed in the network following reassignment of frequencies. This activity must be carried out after the auction has been completed, when frequencies have been reassigned, and the scope of network changes understood.

APPENDICES

4 ANNEX A: ASSUMPTIONS AND INPUT DATA

This section summarises assumptions and inputs used when developing the models used by PA to answer the questions posed by the MEZA. This section is split into four sections:

- Subscriber inputs and assumptions;
- Data traffic inputs and assumptions;
- Geographic inputs and assumptions;
- Coverage and capacity inputs and assumptions; and
- Network inputs and assumptions.

4.1 SUBSCRIBER MODEL

The subscriber model produces a forecast of mobile subscribers by type:

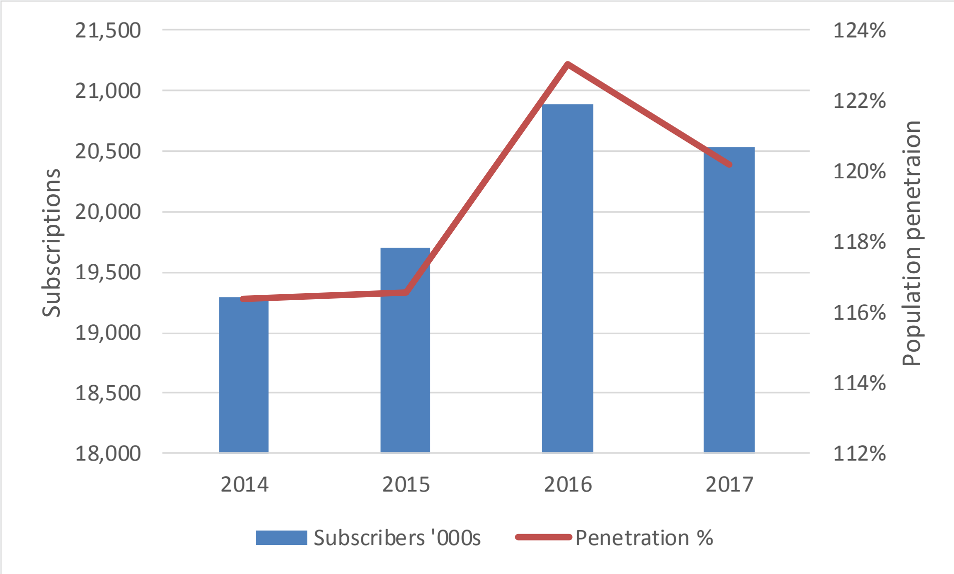
- Non-Smartphone subscribers;
- Smartphone subscribers;
- Data-only service subscribers; and
- M2M subscribers.

Technology splits are then applied to the subscriber forecasts such that each type of mobile subscriber is split between:

- 2G subscribers;
- 3G subscribers;
- 4G subscribers; and
- 5G subscribers,

The model categorises the subscriber according to the most advanced technology that the subscriber's device is capable of. Market shares of the four MNOs are applied by subscriber type and technology.

Area	Inputs and assumptions used
Netherlands population	Historical and forecast population data produced by Centraal Bureau voor de Statistiek (CBS) has been used as an input to the model.
Historical subscriber data	Market data from Autoriteit Consument & Markt (ACM) telecommonitor for 2017 segments the market into Prepaid, Postpaid, MVNO, M2M and Data only subscribers. This has been used as the basis for the development of the market model.
Mobile penetration	Penetration of mobile services, excluding M2M and data only subscriptions, is currently about 120%, as shown in Figure 8, based on inputs from ACM and CBS. **Figure 8: Subscriber growth and penetration of mobile services in the Netherlands**

<table>
<tr><th>Area</th><th>Inputs and assumptions used</th></tr>
<tr><td></td><td>


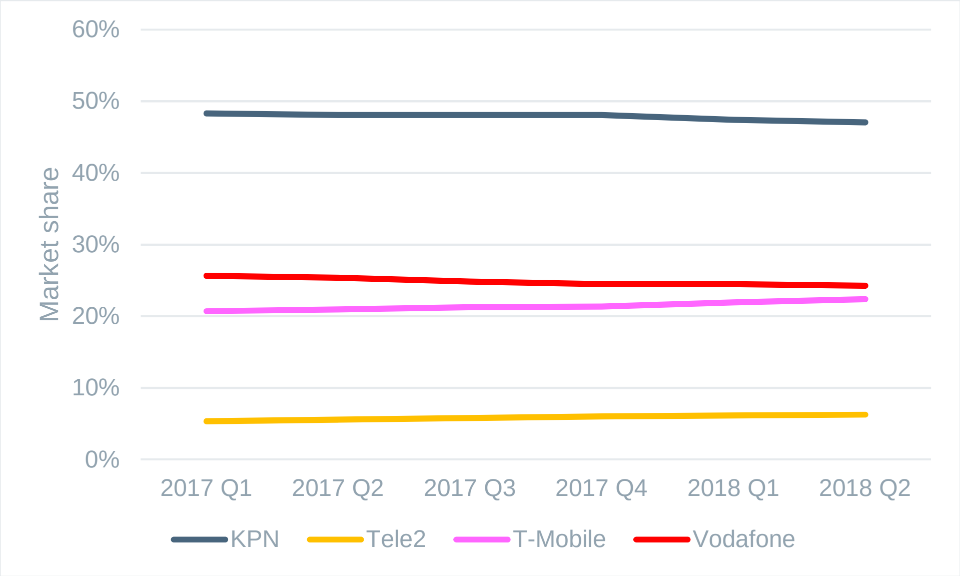
Source: ACM, CBS, PA analysis
This level of penetration is assumed to be flat, continuing at today's level of 120%. This provides the base for the forecast of prepaid and postpaid subscribers.
<table>
<tr><th>Total subscribers '000s</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th></tr>
<tr><td>Penetration</td><td>123%</td><td>120%</td><td>120%</td><td>120%</td><td>120%</td><td>120%</td><td>120%</td><td>120%</td><td>120%</td><td>120%</td><td>120%</td></tr>
<tr><td>Population '000s</td><td>16,979</td><td>17,082</td><td>17,182</td><td>17,262</td><td>17,334</td><td>17,499</td><td>17,464</td><td>17,526</td><td>17,588</td><td>17,649</td><td>17,710</td></tr>
<tr><td>Total subscribers</td><td>20,890</td><td>20,532</td><td>20,619</td><td>20,715</td><td>20,801</td><td>20,999</td><td>20,957</td><td>21,032</td><td>21,106</td><td>21,179</td><td>21,252</td></tr>
</table>
This excludes M2M subscriptions.
</td></tr>
<tr><td>Prepaid and postpaid subscribers</td><td>Ovum's forecast for the development of the prepaid and postpaid subscriber market has been applied to a forecast of the total subscriber numbers in order to determine how many are prepaid and how many are postpaid.</td></tr>
<tr><td>Smartphone and non-smartphone users</td><td>Ovum's forecast of the growth in penetration of smartphones in the Netherlands market has been applied to historical data regarding penetration of smartphones among prepaid and postpaid users from tp:research.

Ovum's forecast of the split between smartphone and non-smartphone users has been applied to prepaid and postpaid subscriber numbers to generate the number of smartphone and non-smartphone users.

It is assumed that there are no non-smartphone 4G or 5G users.</td></tr>
<tr><td>Data only user forecast</td><td>The growth rate from Ovum's forecast of growth in the number of data-only users has been applied to historical data from ACM to forecast the growth in the number of data-only users in the Netherlands.</td></tr>
<tr><td>M2M user forecast</td><td>The growth rate from Ovum's forecast of the development of M2M subscriptions in the Netherlands has been applied to historical figures from ACM to forecast the number of M2M users in the Netherlands.</td></tr>
<tr><td>Smartphone, non-smartphone and data only technology split</td><td>Subscribers in the Netherlands have rapidly adopted high speed LTE services. The proportion of mobile users using LTE increasing from 59% in Q3 2017 to 83% in Q3 2018.[7]

The 5G subscriber forecast is developed using the GSMA forecast of 31% of subscribers using 5G by 2025</td></tr>
<tr><td>M2M technology split</td><td>The split between technologies used to support M2M subscriptions has been derived from Cisco's VNI Mobile Forecast, which includes a split in technology used to provide M2M services for western Europe.</td></tr>
</table>

[7] "Dutch 4G smartphones penetration rises to 88% in Q3", Telecompaper, 10/10/2018

Area	Inputs and assumptions used
MNO market shares	Publicly available information collected from each MNO plus information from tp:research and ACM regarding market shares, shown in Figure 9, has been used to carry out historical analysis. We have assumed the market remains stable, with four MNOs remaining in the market and market shares remain constant over the period up to 2026. **Figure 9: Market shares have remained stable over the past two years**  Source: tp:research Tele2 market share of 2G and 3G subscribers is assumed to be 0%. 2G and 3G subscriber market shares are allocated according to relative size of KPN, T-Mobile and Vodafone subscriber bases.
Impact of merger	The merger of T-Mobile and Tele2 will result in an MNO that has a combined market share of almost 30%. This market share varies depending on the technology used. We have assumed that the merged T-Mobile/ Tele2 maintains this market share.

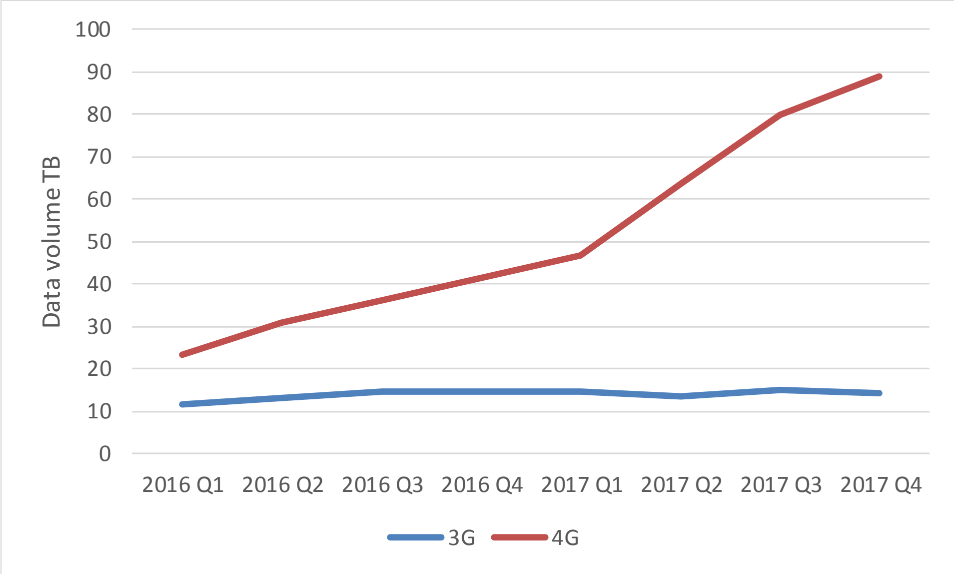
4.2 DATA TRAFFIC

The data traffic forecast is generated by applying estimates of monthly data traffic for each subscriber type by technology to the forecast of subscribers.

Area	Inputs and assumptions used
Historical traffic splits	Figure 10 shows that 4G traffic has increased by almost four times over the past two years. Over the same period 3G traffic carried in the Netherlands has increased by 25%.

Area	Inputs and assumptions used

Figure 10: Quarterly traffic on 3G and 4G networks in the Netherlands



Source: ACM

4G traffic per subscriber	Forecasts for 4G traffic per subscriber by type are derived from Cisco VNI Mobile Data estimates for western Europe for 2016 and forecast for 2021, extrapolated out to 2026. The forecasts exclude data traffic generated by smartphone and data-only subscribers that is offloaded onto Wi-Fi
3G vs 4G multiple	4G subscribers are assumed to generated 2.7x more data than 3G subscribers, based on ACM data regarding 3G and 4G data traffic for 2016 and 2017.
4G vs 5G multiple	5G subscribers are assumed to generate 1.5x more data than 4G subscribers. This is a conservative estimate compared with the Cisco forecast of 4x by 2025. This factor is applied to 4G subscriber/ month data volumes.
Peak hour traffic	The traffic in peak hour has been based on the split in traffic between operators, rather than the split in subscribers. as statistics show that e.g. Tele 2 and T-Mobile carry a disproportionately high amount of traffic compared to the percentage of subscribers.

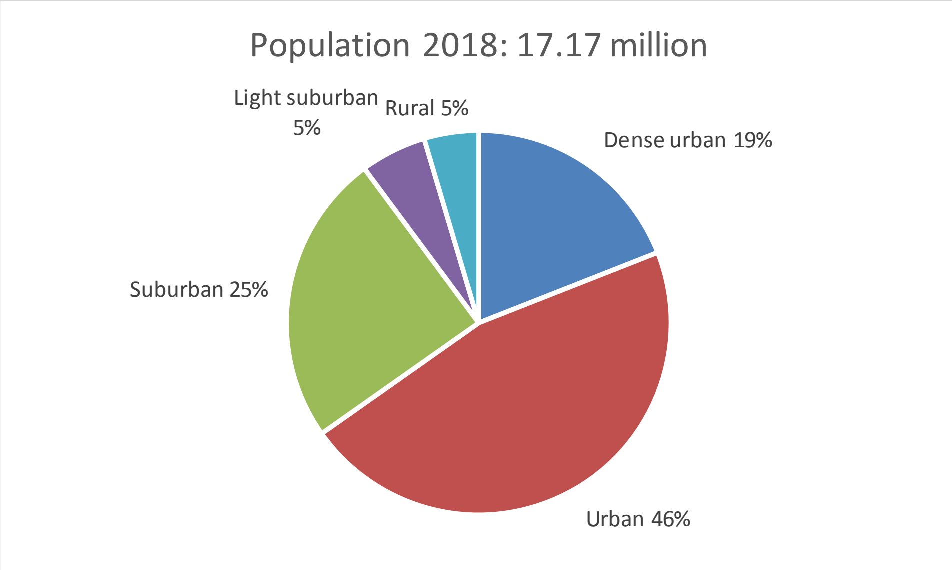
4.3 COVERAGE MODEL

The geographical model uses input data presented in GIS format regarding the population distribution and administrative borders within the Netherlands to calculate the population density of the country to define geotypes and population density of each geotype.

Area	Inputs and assumptions used
MNO network deployment	The Agentschap Telecom database of mobile sites locates each site by latitude and longitude with the Netherlands. It also provides information regarding how each site is used (spectrum band and technology deployed) and height and power output. The location information was loaded into GIS and the network information analysed to understand the distances between cell sites, and the cell site locations by geotype. These inputs were used to define coverage, and how it changes to meet the MEZA target of 98% per municipality
Geotypes	For the sake of consistency with other reports produced for MEZA, we have used population densities derived from a report by Stratix, expressed in terms of people per km2, to define geotypes[8]. These geotypes are:

[8] “Cost elements in the rollout of 5G networks in the Netherlands”, Stratix, 05/04/2018

Area	Inputs and assumptions used
	• Dense urban – with a population density of at least 7,959 people per km^2 • Urban – with a population density of 3,119-7,958 people per km^2 • Suburban – with a population density of 782-3,118 people per km^2 • Light suburban – with a population density of 112-781 people per km^2 • Rural – with a population density of less than 112 people per km^2.
Municipalities	CBS data from Wijk- en Buurtkaart 2018 (District and Neighbourhood Map) was used to define boundaries of municipalities, and therefore the areas of the municipalities in order to carry out the analysis regarding the impact of putting in place the 98% coverage requirement. The diagram below shows the areas of the municipalities excluding the nature reserves.  In total there are 380 municipalities in the Netherlands.
Nature reserves	The Natura 2000 mapping information was used to exclude the areas defined by the nature reserves, as shown in the diagram below, from the analysis. The areas defined by the Natura 2000 database were removed from the area of the municipalities in order to carry out the analysis regarding the impact of putting in place the 98% coverage requirement. It should be noted that coverage in municipalities provided by base stations located in nature reserves was not excluded from the analysis.

<table>
<tr><th>Area</th><th>Inputs and assumptions used</th></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Population density</td><td>CBS also provides information about population density of each of the neighbourhoods which constitute a municipality. This information was used to allocate population to geotypes. The figure below shows the distribution of population in the Netherlands by geotype. Analysis of data from 2013 and 2018 shows that the population in the Netherlands is shifting towards the dense urban geotype.

</td></tr>
<tr><td>Calculation of service speeds at 98% coverage</td><td>The municipality boundaries are applied to the existing coverage calculation in the GIS tool to identify the municipalities where coverage does not hit the 98% coverage requirement, and therefore where MNOs will need to deploy additional sites.

This coverage requirement is calculated based on KPN, Vodafone, and T-Mobile keeping 2x20 MHz in 2100 MHz band, and winning 2x10 MHz each in 700 MHz. The cell range is used to create a coverage map in GIS, whereby a circle with the calculated range is drawn around each site. The range for rural sites for each operator is calculated based on the assumption that they plan for 6 Mbps in the downlink and 1 Mbps in the uplink with the technology improvements assumed area in place by 2022. The areas without coverage (excluding nature reserves) are calculated individually for each municipality. For the purposes of the model, we have assumed that the areas without coverage in each municipality are contiguous, and they require new sites to provide coverage. It is assumed that smaller non-contiguous areas can be covered by adding more sectors or increasing the frequency bands of existing sites, which balances out the need for new sites in other</td></tr>
</table>

Area	Inputs and assumptions used
	non-contiguous areas without coverage. The data rates for 2022 and 2026 are recalculated using the new data.
Distribution of active subscribers	The distribution of active subscribers is derived from the population density in each geotype with a user concurrency model. It is assumed that the number of active subscribers is constant within the average cell radius, but gradually drops to a lower level corresponding to a less populated geotype outside the average cell radius. It is assumed that where multiple sectors per cell are used, the active users are distributed uniformly across all sectors subject to the drop above a certain cell radius as described above.

4.4 CAPACITY MODEL

The capacity model assumes that there is no limitation on service levels that could be a consequence of the backhaul or core networks. Therefore, only the radio network throughput is considered in the model.

Area	Inputs and assumptions used

Current spectrum allocation

Operator	Unit	Direction	700	800	900	1800	2100	2600
KPN	MHz	Uplink	-	10.00	10.00	20.00	20.00	10.00
KPN	MHz	Downlink	-	10.00	10.00	20.00	20.00	10.00
KPN	MHz	TDD	-	-	-	-	-	30.00
Vodafone	MHz	Uplink	-	10.00	10.00	20.00	20.00	30.00
Vodafone	MHz	Downlink	-	10.00	10.00	20.00	20.00	30.00
Vodafone	MHz	TDD	-	-	-	-	-	-
T-Mobile	MHz	Uplink	-	-	15.00	30.00	20.00	5.00
T-Mobile	MHz	Downlink	-	-	15.00	30.00	20.00	5.00
T-Mobile	MHz	TDD	-	-	-	-	-	20.00
Tele 2	MHz	Uplink	-	10.00	-	-	-	25.00
Tele 2	MHz	Downlink	-	10.00	-	-	-	25.00
Tele 2	MHz	TDD	-	-	-	-	-	-

700 MHz spectrum allocation – minimum service level

There is 2x30 MHz of spectrum available in the 700 MHz band. We have assumed that each of the MNOs in the Netherlands will obtain equal amounts of spectrum, i.e. 2x10 MHz.

Concurrent users

The percentage of concurrent users is assumed to increase from 2% in 2018 to 4% in 2026 in all geotypes except in dense urban areas, where concurrent usage will increase from 4% to 6%, as shown in the table below. The dense urban geotype has a concentration of business premises and large travel intersections, and subscribers are more likely to use mobile data on their mobile devices than in other areas.

Geotype	Concurrently active users	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Dense urban	Percentage concurrently active users	3.6%	3.8%	4.0%	4.2%	4.4%	4.7%	4.9%	5.2%	5.4%	5.7%	6.0%
	CAGR concurrently active users	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%
Urban	Percentage concurrently active users	1.7%	1.8%	2.0%	2.2%	2.4%	2.6%	2.8%	3.1%	3.4%	3.7%	4.0%
	CAGR concurrently active users	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%
Suburban	Percentage concurrently active users	1.7%	1.8%	2.0%	2.2%	2.4%	2.6%	2.8%	3.1%	3.4%	3.7%	4.0%
	CAGR concurrently active users	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%
Light suburban	Percentage concurrently active users	1.7%	1.8%	2.0%	2.2%	2.4%	2.6%	2.8%	3.1%	3.4%	3.7%	4.0%
	CAGR concurrently active users	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%
Rural	Percentage concurrently active users	1.7%	1.8%	2.0%	2.2%	2.4%	2.6%	2.8%	3.1%	3.4%	3.7%	4.0%
	CAGR concurrently active users	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%	9.1%

MNO planning input

MNOs are assumed to plan network capacity to deliver 6 Mbps in the downlink and 1 Mbps in the uplink, on the assumption that it aims to give the typical user an experience that supports streaming high-quality audio and video as well as high speed mobile broadband services.

MIMO

It is assumed that a higher order MIMO brings a factor of 1.8 improvement over a lower order MIMO. For example, 2x2 MIMO is 1.8 faster than SISO, 4x4 MIMO is 1.8 faster than 2x2 MIMO, etc.

Resource allocation

It assumed that resource allocation algorithms known as schedulers aim for equal speed for all users regardless of their distance from the base station. The model deploys an iterative resource allocation algorithm which converges to a speed which as similar as possible for all users, and the frequency resources across all bands are 100% utilised. The users farthest from the base station are allocated to the lower frequency bands, the users nearest to the base station are allocated to the higher frequency bands.

Area	Inputs and assumptions used
	Voice services are assumed to have a negligible impact on resource allocation as they are low capacity despite having higher priority in resource allocation.
TDD	It is assumed that where TDD is used, 90% of the capacity is used for downlink, and 10% of the capacity is used for uplink.
LTE carrier bandwidth	The capacity calculations are based on 10 MHz LTE carrier. The capacity for 5 MHz or 20 MHz carriers is derived from the 10 MHz calculations, differences in signalling overhead, guard bands, background noise etc. are not considered.
Capacity enhancements required to mitigate loss of 2100 MHz spectrum	The Agentschap Telecom database provides information about the average number of cells per site that each MNO has deployed. This information is disaggregated by technology, and by frequency band. This information can be used to understand the degree to which an MNO needs to increase capacity, by changing the number of sectors per site in the 1800 MHz or 2600 MHz bands to increase capacity available, and therefore raise service levels to the level prior to the loss of 2100 MHz spectrum.
Service level with 95% probability	Service levels at 95% probability is calculated for each MNO by discarding the cells whose cell radius falls within the top 5% for each geotype. This has the effect of reducing the average and maximum cell radius, and therefore the enhancing the achievable service level in each geotype.

4.5 NETWORK INPUTS AND ASSUMPTIONS

The majority of site information has been derived from the site database managed by Agentschap Telecom. This provides information about:

- The location of cells in the Netherlands;
- Technology deployed at each cell;
- The frequencies in use at each cell;
- The transmit power of the cell;
- The height of the site;
- The number of sectors in use in each cell.

This information is available for each of the MNOs.

Area	Inputs and assumptions used
Other constraints on service speeds	This analysis focuses on the air interface and the handset and does not consider other factors that could constrain maximum service speeds, such as the capacity of the backhaul connecting each site or the core network. We have assumed that these other factors do not constrain the maximum service speeds users could experience.
Number of and distance between sites	We mapped the location of the cells in GIS to understand the number of cells operated by each MNO in each of the geotypes. This analysis was carried out for sites both including those located in nature reserves and again excluding those located in nature reserves. This enabled us to understand the minimum, average and maximum distances between sites, both including and excluding sites located in nature reserves.
Technology deployed in each band	**The three largest MNOs use their spectrum holdings in broadly the same way, as shown in** Table 16: • All three maintain their GSM networks in the 900 and 1800 MHz bands; • All three have deployed UMTS in the 2100 MHz band, but only KPN and T-Mobile have used the 900 MHz band for UMTS; • All have deployed LTE in the 1800, 2100 and 2600 MHz bands. However, KPN and Vodafone have deployed LTE in the 800 MHz band, whereas T-Mobile has deployed LTE in the 900 MHz band. Tele2 has used its holdings in the 800 and 2600 MHz bands to deploy LTE networks.

<table>
<tr><th>Area</th><th>Inputs and assumptions used</th></tr>
<tr><td></td><td>
Table 16: Technologies deployed by the MNOs in each band
<table>
<tr><th>Band</th><th>KPN</th><th>Tele2</th><th>T-Mobile</th><th>Vodafone</th></tr>
<tr><td>800 MHz</td><td>LTE</td><td>LTE</td><td>-</td><td>LTE</td></tr>
<tr><td>900 MHz</td><td>GSM, UMTS</td><td>-</td><td>GSM, UMTS, LTE</td><td>GSM</td></tr>
<tr><td>1800 MHz</td><td>GSM, LTE</td><td>-</td><td>GSM, LTE</td><td>GSM, LTE</td></tr>
<tr><td>2100 MHz</td><td>UMTS, LTE</td><td>-</td><td>UMTS, LTE</td><td>UMTS, LTE</td></tr>
<tr><td>2600 MHz</td><td>LTE</td><td>LTE</td><td>LTE</td><td>LTE</td></tr>
</table>
Source: Agentschap Telecom, PA analysis
</td></tr>
<tr><td>Carrier aggregation</td><td>PA has assumed that all the MNOs are able to deploy intra-band carrier aggregation to enable non-contiguous spectrum blocks to be managed a single block.</td></tr>
<tr><td>Network attributes</td><td>For each of the MNOs, the Agentschap Telecom database was used to derive input assumptions for each geotype, regarding:
• The number of cells where different technologies (2G, 3G and 4G) are deployed using different frequencies;
• The average number of sectors in use at each site for each technology and frequency;
• Distances between cells and cell sizes;
• Average height of a base station by technology and by frequency; and
• Average power of a base station by technology and by frequency.</td></tr>
<tr><td>Impact of merger</td><td>The merger between T-Mobile and Tele2 will lead to the integration of the networks and operations of both MNOs into a single entity. PA has assumed that the consolidated T-Mobile/ Tele2 network will be based on the T-Mobile network. Mobile networks operate as integrated entities, with sites designed in groups, and groups of sites integrated together. Network planners responsible for merging Tele2 and T-Mobile operations will not consolidate the networks on a site-by-site basis, but rather build on the network that offers the best option for supporting the combined customer base. We believe that the T-Mobile network is denser than the Tele2 network, and also offers better coverage than the Tele2 network, and so the T-Mobile network will be used as the starting point for consolidating the networks.

In reality there will be circumstances where the Tele2 site will be retained. There may be sites that are important to specific Tele2 customers, and there may be Tele2 sites that offer a commercial advantage compared to T-Mobile sites. The merged entity may therefore choose to maintain these sites on the basis of commercial, or other, decisions. These exceptions should not affect the principle that T-Mobile sites are maintained, and the Tele2 sites rationalised, because T-Mobile operates a network that works as an integrated entity and offers better coverage than Tele2.

The consolidated network will need to add capacity to support Tele2 customers. We have assumed that the total capacity provided on Tele2 sites will be deployed across T-Mobile sites. This means that each T-Mobile site is enhanced with additional sectors that cumulatively deliver the amount of capacity required to support the Tele2 customer base.</td></tr>
</table>

5 ANNEX B

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6 ANNEX C: SERVICE LEVELS IN OTHER COUNTRIES

This appendix sets out research information on the current service levels put in place by regulators around world for spectrum, with a focus on the sub-1GHz band. Table 17 summarises the information about each western European country.

Table 17: Coverage obligations and service levels implemented in western European countries for sub-1GHz spectrum

Country	Band MHz	Award year	Coverage obligation	Minimum service level	Location	Proba-bility
Austria	800 900	2013	95% population	• Downlink 1 Mbps • Uplink 0.25 Mbps	Outdoor	NA
Belgium	700	2019	99.8% population	6 Mbps per user	Outdoor	NA
	800	2013	98% population	3 Mbps per user, with a peak period of up to 2 hours where 3 Mbps is not required	Outdoor	NA
Denmark	700 900	2019	Defined locations across Denmark	• Downlink 30 Mbps • Uplink 3 Mbps	Outdoor	NA
France	700 800 900	2011	98% population coverage	Network speeds: • Downlink 60 Mbps for an operator holding at least 2x10 MHz • Downlink 30 Mbps for an operator holding 2x5 MHz	Outdoor	95%
Germany	700 900	2015	98% population	50 Mbps per sector downlink	Outdoor	NA
Ireland	800	2013	70% population	Associated field strength and block error rate	Outdoor	NA
Italy	700	2018	• Individual MNO – 80% population • All MNOs – 99.4% population	"Nominal" 30 Mbps downlink, interpreted to mean average	Outdoor	NA
	800	2011	75% of defined municipalities	2 Mbps per user	Outdoor	NA
Norway	800	2013	• All licensees – 40% population • One licensee with 2x10 MHz – 98% population	2 Mbps minimum average download speed	Outdoor	NA
Portugal	800	2016	Unserved areas	• MEO - 43.2 Mbps • NOS - 4.0 Mbps • Voda - 7.2 Mbps	Outdoor	NA
Spain	800	2011	90% population in municipalities of fewer than 5,000 inhabitants	At least 30 Mbps network speed	Outdoor	NA

Country	Band MHz	Award year	Coverage obligation	Minimum service level	Location	Proba-bility
			For licence holders with a minimum of 2x10MHz			
Sweden	700	2018	For 1 licence holder with 2x10MHz - underserved areas	User specific: • 10 Mbps downlink • 128kbps uplink "in normal conditions"	Outdoor	80% at cell edge
	800	2013	For 1 licence holder - underserved areas	• At least 1 Mbps at some point in a day • Average 750 kbps in a day • Minimum average of 500 kbps for 4 consecutive hours	Indoor	NA
United Kingdom	700	2019	92% land mass	Defined signal strength equal to 2 Mbps downlink in a lightly utilised cell at cell edge	Outdoor	95%
	800	2013	98% population	Defined signal strength equal to 2 Mbps downlink in a lightly utilised cell at cell edge	Outdoor	90%

Source: National regulators

6.1 AUSTRIA

800 and 900 MHz bands

800 and 900 MHz spectrum was auctioned in Austria in 2013. The winners of the licences are required to offer mobile broadband services with downlink speeds of 1 Mbps and uplink speeds of 0.25 Mbps outdoors for either 90% or 95% of the population of Austria. This service level was upgraded to downlink speeds of 2 Mbps and uplink speeds of 0.5 Mbps outdoors for 90% of the population in specific communities.[9]

6.2 BELGIUM

700 MHz band

The 700 MHz spectrum will be allocated in 2019.[10] The IBPT proposes to put in place the following coverage obligations on incumbent operators that obtain 700 MHz spectrum:

- 70% population coverage 1 year after award of the licence;
- 99.5% population coverage after 2 years;
- 99.8% population coverage after 6 years.

The operators will be required to provide a minimum speed per user of 6 Mbps outdoors.[11]

800 MHz band

The 800 MHz spectrum was awarded to operators in 2013. The winning operators are required to meet a coverage obligation of:

[9] https://www.rtr.at/en/tk/multibandauktion_coverage
[10] The Introduction of 5G in Belgium, IBPT, 20/09/2018
[11] Communication regarding the reserved spectrum, the spectrum caps and the coverage obligations for the multiband auction, IBPT, 01/07/2013

- 30% of population by the end of 2015;
- 70% of population by the end of 2017; and
- 98% of population by the end of 2019.

The licensees must offer minimum download speeds of 3 Mbps to customers with a typical device outside.[12] The 3 Mbps requirement must be met 24x7, but the IBPT can define a peak period of up to 2 hours in duration when the requirement does not have to be met.

6.3 DENMARK

700 and 900 MHz bands

Energistyrelsen is proposing to auction 700 and 900 MHz spectrum along with 2300 MHz spectrum in 2019. It has defined a service level for mobile broadband services using the 700 and 900 MHz spectrum of:

- Downlink speeds of a minimum of 30 Mbps; and
- Uplink speeds of a minimum of 3 Mbps.[13]

Three licences will be awarded with different coverage areas, with each licence holder required to cover at least 90% of the area. This obligation can be met by any spectrum held by the MNO. Each coverage area reflects specific locations within Denmark specified by Energistyrelsen, which represent a small proportion of the country.

The accompanying 2300 MHz spectrum licence requires the licence holder to provide a mobile broadband service offering at least 50 Mbps in the downlink and 5 Mbps in the uplink to 98% of the premises in the area at an outdoor location.

6.4 FRANCE

Arcep has defined a level of coverage and an associated service level for mobile broadband services that applies to 700 MHz and 800 MHz spectrum, and the MNOs' existing spectrum holdings in the 900, 1800 and 2100 MHz bands which will expire between 2021 and 2024.

Details of coverage obligations vary between the different licences, but at the highest level MNOs must cover 98% population coverage in metropolitan France by 2027, increasing to 99.6% after 15 years following award of the licences. Arcep has defined a requirement for MNOs to provide broadband services with speeds depending on how much spectrum the operator holds:

- Maximum theoretical speed of more than 60 Mbps in the downlink for an operator holding at least 2x10 MHz of spectrum; and
- Maximum theoretical speed of more than 30 Mbps in the downlink for an operator holding 2x5 MHz of spectrum.[14]

There is a requirement to meet a level of 95% probability of obtaining a connection external to buildings.

6.5 GERMANY

700 and 900 MHz bands

2x30 MHz of 700 MHz spectrum and 2x35 MHz of 900 MHz spectrum was auctioned in 2015, alongside 20 MHz of 1500 MHz spectrum and 2x50 MHz of 1800 MHz spectrum. The spectrum was auctioned with a population coverage obligation of 98% of households across the country, with a minimum of 97% household coverage in each federal state.[15]

The Bundesnetzagentur has not imposed household or user-specific quality parameters associated with the coverage obligation, considering that:

- There are too many variables involved in delivering the service to impose latency or minimum service level obligations on an individual subscriber or household level;
- Competition and the implementation of new technologies to drive improvements in quality parameters
- Mobile access is a shared medium, and that the number of subscribers sharing the access will determine the user experience.

The BNA has therefore set a minimum downlink transmission rate of 50 Mbps per sector. The aim of the requirement is to ensure general availability of data rates of more than 10 Mbps for users and anticipates that data rates will exceed this level. This obligation applies to a successful bidder independent of the band in which they won the spectrum. However, the Bundesnetzagentur expects that the 700 MHz band will be used by MNOs to

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[12] Information memorandum: Auction of usage rights for the 800 MHz band, IBPT, 26/07/2018
[13] Informationsmemorandum: 700 MHz, 900 Mhz og 2300 MHz-auktionen, Energistyrelsen, 19/09/2018
[14] Decision no. 2018-0684, Arcep, 03/07/2018
[15] Decision reference: BK1-11/003, Bundesnetzagentur, 28/01/2015

extend broadband coverage to the most remote locations. The BNA will measure both the speed delivered by the network, and the service level experienced by the user.

800 MHz band

https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OeffentlicheNetze/Mobilfunknetze/Projekt2016/Z_Auktion2010.html?nn=267704

800 MHz spectrum was auctioned in 2010. The licences included an obligation to cover 90% of the population, including the obligation to provide coverage in towns of different sizes, with smaller towns with fewer than 5,000 inhabitants the highest priority.[16] No specific service levels associated with this obligation.

6.6 IRELAND

800, 900 and 1800 MHz bands

The Irish regulator awarded licences with liberalised use in 2013. Licensees were required to cover at least 70% of the population within 3 years of award of a licence. Rather than a service-specific specification, the regulator defined field strength and block error rate defined for each technology used and bandwidth available as part of the licences.[17]

6.7 ITALY

700 MHz band

The auction in 2018 of 700 MHz spectrum in Italy placed coverage obligations on:

- Individual spectrum licence winners, which are required to provide services using their spectrum holdings to 80% of the population within 3 years of availability of spectrum, including all provincial capitals and municipalities with a population of greater than 30,000; and
- All MNOs collectively which obtained 700 MHz spectrum. They are required to provide coverage to 99.4% of the population and can use roaming arrangements to meet this obligation.

For the purposes of these obligations, winning bidders can use other spectrum bands provided they can also use consumer devices capable of supporting 5G services in the 700 MHz band.[18]

The Italian regulator AGCOM requires MNOs to provide a “nominal” download speed of 30 Mbps. This is interpreted to reflect the need for an average rather than an absolute minimum.

800 MHz band

The 800 MHz spectrum was auctioned in Italy in 2011 along with 1800 and 2600 MHz spectrum. Each 800 MHz spectrum block auctioned had an associated list of several hundred small municipalities. The winning bidders were required to use the 800 MHz spectrum to provide data services with a minimum data rate to a single user of at least 2 Mbps and were obliged to cover at least 75% of the municipalities within 11 years of the award of the spectrum.

6.8 NORWAY

800 MHz band

800 MHz spectrum was auctioned in Norway in 2013. The licence conditions required:

- All licensees to provide access to mobile broadband for 40% of the population within 4 years after obtaining the licence; and
- One licensee with 2x10 MHz to provide access to mobile broadband for 98 % of the population within 5 years after obtaining the licence. The licensee may use frequencies in other bands as well to fulfil the coverage obligations.

For both types of licence, the licence conditions required the licensees to provide a service with an average net download speed of minimum 2 Mbps at any time, outdoors.[19]

6.9 PORTUGAL

800 MHz band

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[16] Draft licence for 800 MHz spectrum, Bundesnetzagentur, 2010
[17] “Amended Liberalised Use Licence for terrestrial systems capable of providing Electronic Communications Services”, Comreg, 17/05/2013
[18] Resolution no. 231/18/CONS, AGCOM, 08/05/2018
[19] Dekningskrav i 800 MHz-båndet, Post og-teletilsynet, 14/08/2013

An obligation to cover 80 parishes that lacked mobile broadband covered was assigned to each 2x5 MHz spectrum lot in the 800 MHz auction. With each of the three incumbent MNOs winning two lots, each had to provide coverage to 160 parishes.

Each of the MNOs is required to provide services that meet a reference speed, based on mobile broadband services provided in 2014. Anacom determined the reference speeds to be:

- MEO - 43.2 Mbps;
- NOS - 4.0 Mbps;
- Vodafone Portugal - 7.2 Mbps.[20]

This reference speed is then reviewed every two years.

6.10 SPAIN

800 MHz band

Licences for 800 MHz spectrum auctioned in 2011. The licences defined a coverage obligation for MNOs holding 2x10 MHz of spectrum. By 2015 the licence holders were required to provide services of on average 30 Mbps to 90% of the population in municipalities of fewer than 5,000 inhabitants, equivalent to 10.5 million people, by 2015.[21] This was revised in 2018 to reflect the slower rollout of services, with the timescales for achieving the 90% target extended to 2020.

6.11 SWEDEN

700 MHz band

Sweden proposes to award one 700 MHz licence with 2x10 MHz of spectrum with associated obligations for coverage in underserved areas that lack outdoor coverage for voice and/ or data services. Licence holders are obliged to provide data services of at least 10 Mbps in the downlink and 128 kbps in uplink “in normal conditions”, with a cell edge coverage probability of more than 80%.[22] A further six blocks of spectrum in the 700 MHz band, including both FDD and SDL licences, will be auctioned without coverage obligations.

800 MHz band

Sweden awarded one 800 MHz licence with an associated commitment to cover a prioritised list of homes and businesses that do not benefit from a specified data rate up to a rollout cost of SEK300 million. The licence holder is required to provide services with a bit rate of 1 Mbps or higher indoors, with:

- A bit rate of at least 1 Mbps at some point in time in a day;
- An average rate of at least 750 kbps in a day; and
- An average rate for four consecutive hours when the speed is at its lowest of at least 500 kbps.[23]

6.12 UNITED KINGDOM

700 MHz band

Ofcom intends to auction 700 MHz spectrum in 2019. It is considering service levels it can set to maximise consumer benefits by:

- Focusing on rural areas;
- Safeguarding benefits for the nations of the UK;
- Delivering real benefits for consumers; and
- Providing MNOs with the flexibility to use their expertise.[24]

Ofcom’s proposed approach for the 700 MHz band is to put in place obligations that cover:

- Premises, providing indoor coverage to 60% of the 200,000 premises in rural areas that lack coverage;

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[20] https://www.anacom.pt/render.jsp?contentId=1381272

[21] Acuerdo por el que se emite informe sobre el Proyecto de orden por la que aprueba el plan para proporcionar coveratura que permita el access a servicios de band ancha a verlocided de 30 Mbps o superior, a ejecutar pro los operadores titulares de concesiones demanialses en al band de 800 MHz”, CNMC, 22/02/2018

[22] Open invitation to apply for licences to use radio transmitters in the 700 MHz band: Appendix A: Licence conditions, PTS, 10/07/2018

[23] “Mobile Coverage Obligations: ECC Report 231”, Electronic Communications Committee, 06/03/2015

[24] “Improving Mobile Coverage: Proposals for coverage obligations in the award of the 700 MHz spectrum band”, Ofcom, 9/03/2018, p.

- Outdoor coverage across 92% of the UK landmass, with minimum coverage levels of 92% in England and Norther Ireland, 83% in Wales and 76% in Scotland.

The service provided in these areas must meet Ofcom's connectivity definition of a 'good' service:

- Voice calls which can be made for at least 90 seconds without interruption; and
- Data services which should offer data rates of 2 Mbps for every 95% of the time.

This is equivalent to a signal strength of -105dBM across the landmass covered in any 100m2 pixel.

These coverage obligations must be complied with within 3 years of the award of the licence.

800 MHz band

Ofcom auctioned 800 MHz licences in 2013. O2's licence was auctioned with an obligation to provide services:

- With a sustained downlink speed of 2Mbps with 90% confidence when the network is lightly loaded to users; and
- Across an area within which 98% of residential premises in the UK, and 95% of the population of each of the four nations that make up the United Kingdom live.[25]

[25] "The award of the 800 MHz and 2.6 GHz spectrum: Information memorandum update", Ofcom, 12/11/2012, p.25

7 APPENDIX D: USER EQUIPMENT CATEGORIES

7.1 DEVICE CATEGORIES

Table 18 shows, for each of the device categories defined in the 3GPP release specifications for LTE, the technical capabilities and maximum downlink and uplink speeds of the device, assuming the availability of 20 MHz of spectrum.

Table 18: 3GPP device categories and capabilities

3GPP Release	Category	QAM Support		Max MIMO Layers	Max Downlink Mbps	Max uplink Mbps
		Downlink	Uplink			
8 (LTE)	1	-	-	1	10	5
	2	-	-	2	50	25
	3	-	-	2	100	50
	4	-	-	2	150	50
	5	-	64	4	300	75
10 (LTE-A)	6	64	-	2 or 4	300	50
	7	64	-	2 or 4	300	100
	8	-	64	8	3000	1500
11 (LTE-A)	9	64	-	2 or 4	450	50
	10	64	-	2 or 4	450	100
	11	64, 256	-	2 or 4	600	50
	12	64, 256	-	2 or 4	600	100
12 (LTE-A)	13	256	64	2 or 4	390	150
	14	256	64	8	3900	1000
	15	64, 256	64	2 or 4	750	220
	16	64, 256	64, 256	2 or 4	1000	100
13 (LTE-A Pro)	17	256	64, 256	8	25000	2100
	18	64, 256	64, 256	2,4 or 8	1200	200
	19	64, 256	64, 256	2,4 or 8	1500	13500
14 (LTE-A Pro)	20	64, 256, 1024	64, 256	2,4 or 8	2000	300
	21	64, 256	64	2,4 or 8	1400	310
15	22	64, 256, 1024	64, 256	2,4 or 8	2300	420
	23	64, 256, 1024	64, 256	2,4 or 8	2600	530
	24	64, 256, 1024	64, 256	2,4 or 8	3000	630
	25	64, 256, 1024	64, 256	2,4 or 8	3100	740
	26	64, 256, 1024	64, 256	2,4 or 8	3500	850

Source: 3GPP

7.2 DEVICE MARKET SHARES

Table 19 shows the market shares and categories for the top 10 smartphones in use in the Netherlands market, based on a survey of users carried out by Statista.

Table 19: Market share and categories of top 10 smartphones in use in the Netherlands

Manufacturer	Model	Market share	Category
Apple	iPhone 5S	6.2%	3
Apple	iPhone 6	6.0%	4
Apple	iPhone 6s	4.3%	6
Apple	iPhone SE	4.2%	4
Samsung	Galaxy S7	3.8%	9
Samsung	Galaxy A5	3.6%	6
Samsung	Galaxy S5	3.4%	6
Apple	iPhone 7	3.2%	9
Samsung	Galaxy A3	2.7%	4
Samsung	Galaxy J5	2.6%	6

Source: Statista, manufacturer information

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