Commission for
Communications Regulation

Spectrum award – 3.6 GHz band.

Technical advice from Plum Consulting concerning potential rights of use in the 3.6 GHz band.

Report 2: Rollout considerations and timelines.

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Technical advice concerning potential rights of use in the 3.6 GHz band.

Report 2: Rollout considerations and timelines

A Report for ComReg

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June 2015

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Executive Summary

This report provides analysis of the likely roll-out considerations and timelines for services under a new licensing regime for the 3.6 GHz band based on the development of standards, predicted availability of equipment and likely utilisation of the band in other countries. Inputs to ComReg's consultation 14/101 have also informed this analysis.

Developments in the 3.6 GHz band

Whilst the 3.6 GHz band is used in a number of countries throughout Europe and internationally to provide fixed wireless access broadband services these have predominantly used WiMAX equipment and most recent licensing has been to award spare frequencies, for this purpose, on a national or regional basis. However the 3.6 GHz band was identified at the World Radio Conference 2007 (WRC-07) for IMT (International Mobile Telecommunication) by certain countries[1] and despite it not becoming a global allocation it was accepted by many countries for mobile services subject to some specific obligations (cross-border deployments and power limitations). The 3.6 GHz band[2] has since been identified in September 2012 by 3GPP for deployment of LTE-TDD and is considered suitable for the deployment of small cells to support higher data rates using LTE-Advanced (Release 10). The WiMAX Release 2 (IEEE 802.16m) standard can also be deployed in the 3.6 GHz band and similar to LTE-Advanced is in accordance with the IMT-Advanced (4G) specifications defined by the ITU (i.e. meets the required peak data rates of 1 Gbps / 100 Mbps for fixed / mobile users in the downlink).

The 3.6 GHz band is under consideration at the forthcoming World Radio Conference (WRC-15) to provide a harmonised allocation for the mobile service on a primary basis to support the development of mobile broadband.

It has been noted that there is a general trend of migration away from WiMAX to LTE by existing licensees with a migration path being identified / available from WiMAX to TD-LTE. In fact at least one FWALA operator has indicated that they would migrate from WiMAX to LTE. There have been a number of trials associated with plans to roll-out LTE TDD and there are a number of planned spectrum awards, and associated consultations, but apart for Japan and Slovakia there are no recent awards. There is currently limited equipment availability in the 3.6 GHz band with the majority of end user devices being for fixed deployments.

On balance the view of the Study Team is that the 3.6 GHz band will not become mainstream for mobile broadband using LTE TDD technology until 2020 and the outcome of the forthcoming World Radio Conference (WRC-15) may well have an influence on future equipment availability especially in respect of the 3600 – 3800 MHz band which is used extensively in some countries for satellite services.

Implications for existing FWALA deployments

Under any new licensing regime it is expected that ComReg will implement the requirements of EC Decision 2014/276/EU amending the Decision 2008/411/EC, namely:

- TDD mode for 3600 – 3800 MHz
- TDD preferred mode for 3400 – 3600 MHz
- Assigned block sizes to be multiples of 5 MHz

[1] See footnote 5.430A of the Radio Regulations

[2] Identified as bands 42 (3400 – 3600 MHz) and 43 (3600 – 3800 MHz).

- Base stations and terminal stations to comply with specified Block Edge Masks.

This has implications for the existing FWALA operators as although the existing transmitter bandwidths can be fitted in 5 MHz blocks and also the block edge masks met by the implementation, as necessary, of internal additional guard bands this might not be the most spectrally efficient outcome. A number of the existing networks deploy FDD technology and even if ComReg were to decide to implement FDD in the 3400 – 3600 MHz band the available spectrum would be limited to two paired blocks – one of 25 MHz and the other of 15 MHz – due to the State Services operating in the band.

1 Introduction

This report provides analysis of the likely roll-out considerations and timelines for services under a new licensing regime for the 3.6 GHz band based on, amongst other things, the development of standards, predicted availability of equipment and likely utilisation of the band in other countries. Inputs to ComReg's consultation 14/101 have also informed this analysis.

In the following sections we provide further information that forms the basis of our conclusions.

1.1 Network Rollout

There are a number of factors that impact on network roll-out once spectrum has been obtained through a licensing process. These include:

- **Services.** The services that are planned could have a significant impact on network roll-out and this is discussed further in Section 1.2 below.
- **Licence Conditions.** The licensing conditions[3] will impact on network planning as these may determine minimum data rates to be provided to users, coverage requirements, and specific technical requirements to maximise use of spectrum and minimise potential for interference.
- **Availability of Standards**. In the case of many applications / services the availability of relevant standards is an important consideration to ensure that equipment will be available in the market place and there are economies of scale to minimise equipment costs. Increasingly standardisation is required on a regional / global basis as well as harmonised frequency bands.
- **Availability of Equipment.** Network roll-out cannot commence until network and terminal equipment is available from vendors. For equipment suppliers to develop equipment they will require confidence in the likely demand in terms of timescales and volumes especially where there may be a need to prioritise developments as in the case of cellular networks where a number of frequency bands are available / licensed. Operators will normally want to ensure that there are a number of potential suppliers and in the case of terminals there needs to be a choice to attract potential users.
- **Access to Sites.** The potential to use existing sites and gain access to new ones will impact on network planning.

1.2 Services

There are a number of considerations in respect to the network planning and rollout for the 3.6 GHz band as noted above but an important consideration is the likely use of the band. It is currently used to provide Fixed Wireless Access but in the future it could be used to support Fixed Wireless Access r small cells for mobile, and / or other services[4].

[3] It is assumed that prior to licence application the licensee will have undertaken a business case analysis to identify the market and costs of delivering the services based on the licence conditions published as part of the licence award process.

[4] For example the band may be used to provide backhaul for the mobile networks. There are other services that may require spectrum, such as M2M and electronic news gathering, which might also consider using the band.

Fixed Wireless Access networks typically deploy base stations at high points, using higher towers and transmitter powers to maximise coverage. The user equipment antenna is generally externally mounted on a building and is directional and points towards the base station. The availability of more spectrally efficient technologies, as discussed in Section 2 below, provides the potential to support higher speed broadband services to end users compared with some of the existing Fixed Wireless Access Networks.

The 3.6 GHz band also is an attractive option for the deployment of dense small cells to meet the traffic capacity requirements at hot spots in a network. This is because of the bandwidth available which can support growing capacity requirements and also the higher propagation loss (compared with other mobile network frequency bands) which makes it ideal for deploying small cells /denser networks. Typically such deployments will use limited height base stations and lower transmitter powers and can be deployed at network hot spots indoors or outdoors as required. The user equipment may be mobile and will typically use omni-directional antennas.

Despite the difference in network deployment for FWA and small cell mobile services it is likely that there will be a common technology roadmap (i.e. LTE) to support the required network capacities.

2 Wireless Broadband Standards

2.1 Introduction

The 3.6 GHz band is being used in a number of countries throughout Europe and internationally to provide fixed wireless access broadband services. These services predominantly use WiMAX equipment.

The band is now being identified by industry and standards organisations[5] to support higher data rates using LTE-Advanced (Release 10) and WiMAX Release 2 (IEEE 802.16m) standards that are in accordance with the IMT-Advanced (4G) specifications defined by the ITU. The ITU IMT-Advanced initiative set criteria for inclusion in the IMT-A framework in 2003[6] and candidate technologies were to be submitted by October 2009. Key requirements were for peak data rates of 1 Gbps for fixed services and 100 Mbps for mobile services. Also peak, average and cell edge spectral efficiencies were defined to ensure higher bit rates are available to all users within a cell.

For the purposes of this Study it is assumed that any new licensee will wish to deploy equipment that meets these standards and on this basis information is provided in Section 3.4 on availability of equipment.

In the following sections we provide a brief overview of the current status of standardisation for the only two wireless technologies which meet the requirements of the IMT-A framework.

2.2 3GPP standardisation

The development of standards for LTE and LTE-Advanced (LTE-A) is undertaken within the 3rd Generation Partnership Project (3GPP). The table below provides an overview of the 3GPP Releases that relate to LTE.

Table 2-1: Overview of LTE 3GPP Releases

3GPP Release	Freeze date (Note 1)	Developments in the radio access network
Release 8	2008	Maximum data rates: 300 Mbps downlink, 75 Mbps uplink[7] Channel bandwidths: 1.4, 3, 5, 10, 15 and 20 MHz Modulation: SC-FDMA[8] uplink, OFDMA[9] downlink 4 x 4 MIMO[10] antennas

[5] For example the bands 42 and 43 (3400 – 3600 MHz and 3600 – 3800 MHz respectively) were identified in September 2012 by 3GPP for LTE-TDD

[6] See ITU-R M.1645

[7] See http://www.ijitee.org/attachments/File/v3i12/L16590531214.pdf for the derivation of these data rates.

[8] SC-FDMA – single carrier frequency domain multiple access

[9] OFDMA – orthogonal frequency division multiple access

[10] MIMO – multiple input, multiple output

3GPP Release	Freeze date (Note 1)	Developments in the radio access network
Release 9	2009	Further development of Release 8: Introduction of LTE femtocells (Home eNodeB) Optimisation of random access channel Location services for mobile devices
Release 10	2011	Maximum data rates increased: 3 Gbps downlink, 1.5 Gbps uplink Carrier aggregation (see Release 11 and 12) – aim ultimately is to aggregate 5 separate carriers Higher order MIMO (8 x 8 downlink, 4 x 4 uplink) Relay nodes to support HetNets[11] Enhanced inter-cell interference coordination (eICIC) to improve performance towards edge of cells
Release 11	2013	Enhancements to Release 10 (i.e. carrier aggregation, MIMO, relay nodes, eICIC) Carrier aggregation limited to 2 downlink carriers Coordinated multipoint to allow users simultaneous communication with multiple cells Addition of frequency bands
Release 12	2015	Enhanced small cell developments Carrier aggregation to support 2 uplink, 3 downlink and FDD/TDD carrier aggregation MIMO (3D channel modelling, elevation beam forming, massive MIMO) New and enhanced services: machine type communications, device to device, eMBMS (evolved Multimedia Broadcast Multicast Service)
Release 13	2016	LTE in un-licensed spectrum LTE enhancements (e.g. beamforming, MIMO)

Note 1: The freeze dates provided for the different releases indicate when no further additional functions could be added to that release of a standard. However it may still be necessary to specify detailed protocol and test specifications which would impact on timescales for equipment availability.

Release 10, is for LTE-Advanced (LTE-A) and this standard meets the requirements of IMT Advanced by using carrier aggregation of the Release 8 / 9[12] carriers (referred to as component carriers, CCs) to

[11] A HetNet (Heterogeneous network) supports the interoperation between different types of cells (macro and small) as well as with other technologies such as Wi-Fi.

[12] Release 8 was based on a maximum carrier bandwidth of 20 MHz and used OFDMA in the down-link. The highest peak data rates were 300 Mbps in the down-link and 75 Mbps in the up-link.

increase the available bandwidth and peak data rates accordingly. In addition, other measures have been implemented to increase data rates such as MIMO (multiple input multiple output) antennas.

LTE-A has continued to evolve and additional carrier aggregation options have been added to take account of new frequency bands. Release 11 has introduced a new feature – Co-ordinated Multi Point (CoMP) which is intended to improve the performance of the network at the cell edges. The latest standard nearing the end of development is LTE-A Release 12 and further releases are already planned / underway which will add extra functionality / performance enhancements.

2.2.1 Carrier aggregation

As mentioned previously LTE-A Release 10 uses carrier aggregation of the Release 8 / 9 carriers (referred to as component carriers (CCs)) to increase the available bandwidth and peak data rates accordingly.

The easiest way to arrange aggregation is to use contiguous component carriers in the same frequency bands as shown below but it is also possible to use non-contiguous component carriers[13] or carriers in different frequency bands.

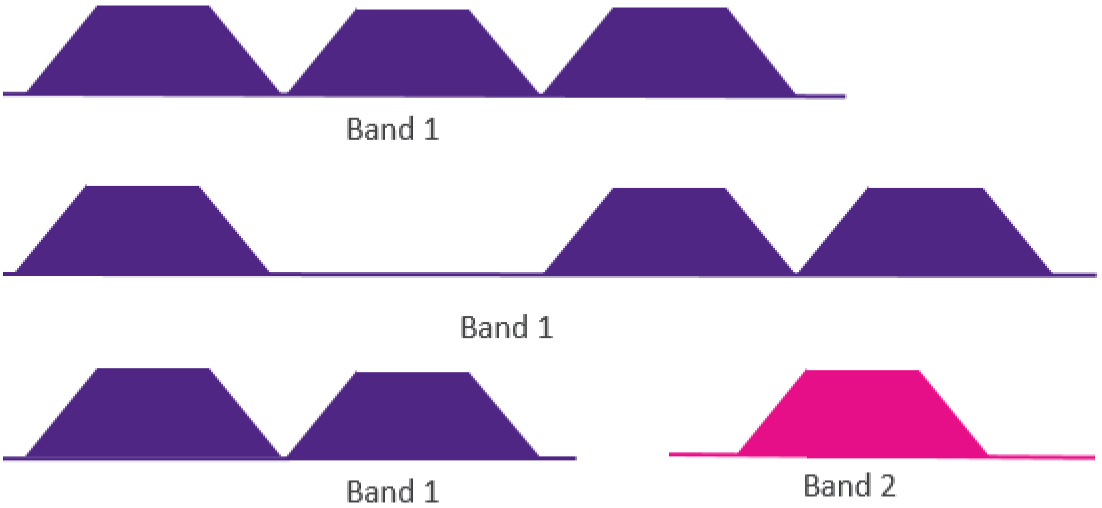
LTE-8 Release 8 User Equipment Categories (Source: 3GPP, http://www.3gpp.org/IMG/pdf/2009_10_3gpp_IMT.pdf)

Category		1	2	3	4	5
Peak rate Mbps	DL	10	50	100	150	300
	UL	5	25	50	50	75
Capability for physical functionalities						
RF bandwidth		20MHz				
Modulation	DL	QPSK, 16QAM, 64QAM				
	UL	QPSK, 16QAM				QPSK, 16QAM, 64QAM
Multi-antenna						
2 Rx diversity		Assumed in performance requirements.				
2x2 MIMO		Not supported	Mandatory			
4x4 MIMO		Not supported				Mandatory

LTE Release 9 included improvements to MIMO and supported MBSFN (Multicast broadcast single frequency network) for mobile TV.

[13] In this instance the component carriers will be separated by a frequency gap.

Figure 2-1: Aggregation of contiguous component carriers (CCs) in same and different frequency bands



Depending on the Release there is the potential to aggregate more or less CCs as shown in the table below:

Table 2-2: Comparison of number of component carriers supported by Releases

Release	Number of possible CCs in downlink	Number of possible CCs in uplink
10	2	None
11	2	1or 2
12	3	2

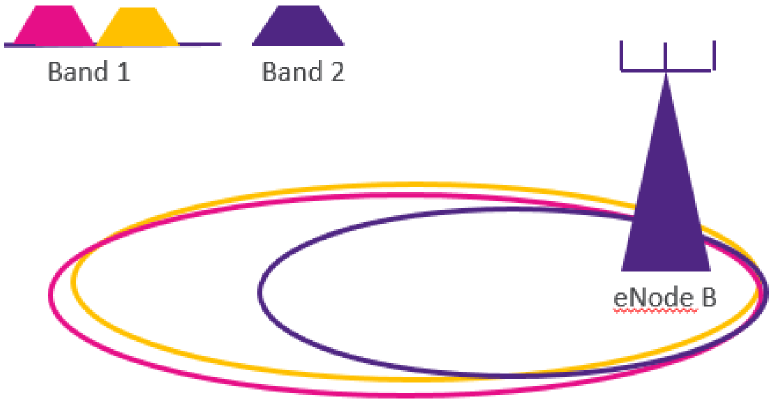
In Release 12 carrier aggregation provides a maximum bandwidth of 100 MHz (5 x 20 MHz).

In terms of planning with carrier aggregation there are a number of serving cells[14] and each corresponds to a component carrier (CC). There is the possibility that the coverage of the serving cells[15] may differ because of the different component frequencies and therefore UE's may not be within the coverage of all the carriers as shown in the figure below. However there is likely to be little difference in the coverage achieved when all the carrier component frequencies are in the same frequency band such as the 3.6 GHz band.

[14] A cell is generally the coverage area provided by a sector of an antenna

[15] The serving cells are defined as Primary and Secondary.

Figure 2-2: Carrier aggregation showing the potential and impact of using different frequency bands



In carrier aggregation there will be a primary component carrier which is the main carrier in any group and it provides both the Radio Resource Control (RRC) as well as carrying data. In addition, there will be one or more secondary component carriers that carry user data. Different terminals may use different carriers. To support carrier aggregation, cross carrier scheduling is necessary and a range of different strategies for scheduling are available to maximise spectrum efficiency.

2.2.2 MIMO (Multiple Input Multiple Output)

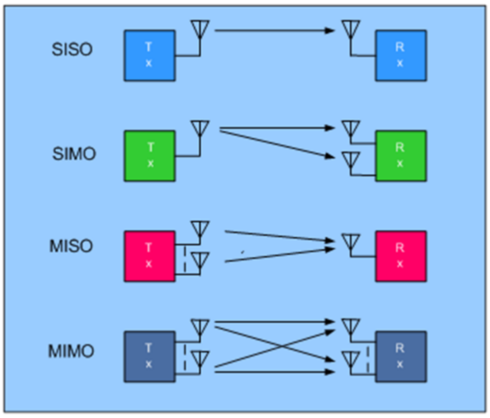
As mentioned above LTE-A uses MIMO, an antenna technology, which enables the overall bit rate and reliability to be increased by using multiple antennas at the transmitter and receiver and so provide a number of different transmission paths. MIMO is particularly effective in urban areas where there is the likelihood of multiple reflections from buildings and other objects and one transmission path may provide a better performance than the others.

The principal benefit of MIMO is there are multiple radio paths and each of these can carry data. In theory, doubling the number of antennas has the potential to double the transmission data rate, however this depends on the radio paths having perfect spatial separation, which in practice is unlikely to be realised. MIMO is less effective in rural locations, especially where there is line of sight between the transmitter and receiver as is the case for Fixed Wireless Access. Practical trials of 3.5 GHz CPE antenna systems in Ireland used for Fixed Wireless Access support 2 antennas[16].

The figure below shows how MIMO is implemented and the multiple transmission paths that result:

[16] "Field trials of LTE with 4×4 MIMO", Johan Furuskog, Karl Werner, Mathias Riback and Bo Hagerman, Ericsson Review, 2010

Figure 2-3: Multiple antenna configuration



SISO – single input, single output

SIMO – single input, multiple output (1xN)

MISO – multiple input, single output (Nx1)

MIMO – multiple input, multiple output (N_1xN_2)

Clearly the more antennas that are deployed the larger the number of alternative paths but there are constraints on the number of antenna elements that may be deployed in practice especially in user devices which are normally limited in size. Also MIMO requires additional processing and this increases with the number of antennas which needs to be balanced against considerations such as battery life[17].

MIMO systems can use different techniques including:

- Spatial diversity where the same signal is transmitted from each antenna but with different coding. The receiver will receive the same signal over a number of different paths and can process the information such that it can operate in poor signal conditions such as near the edge of a cell.
- Spatial multiplexing which provides additional traffic capacity by transmitting two or more different signals using different transmission paths (antenna) between the transmitter and receiver. This requires the use of coding and processing for the receiver to extract the signals. In theory, the maximum number of signals that can be supported is equal to the smaller number of antenna on the transmitter and receiver. Therefore, for example, a transmitter with 4 antenna and a receiver with 2 could potentially support two independent signals.

A major change in LTE-A Release10 is the availability of 8 x 8 down-link and 4 x 8 MIMO in the up-link.

2.2.3 User Equipment (UE)

The UE categories have had to be expanded to support the number of component carriers and also the introduction of MIMO. For example, UE category 8 supports the maximum number of CCs and 8 x 8 spatial multiplexing and 64QAM in the uplink.

[17] This would be of low / no relevance for Fixed Wireless Access.

However, it is still possible, for example, for Release 8 / 9 UEs to be used as they can be allocated resources on any one of the CCs but they will have a poorer performance as they will have access to less bandwidth

The table below provides an overview of the different UE categories. The UE-Category defines a combined uplink and downlink capability as specified in 3GPP TS36.306:

Table 2-3: Summary of different UE categories (Source: www.radio-electronics.com/ and 3GPP)

UE Category	Max. number of DL-SCH transport blocks received in a TTI	Max. number of supported layers for spatial multiplexing in DL	Max. number of UL-SCH transport blocks received in a TTI	Support for 64-QAM in UL	Max. data rate in DL (Mbps)	Max. data rate in UL (Mbps)
1	10 296	1	5 160	No	10	5
2	51 024	2	25 456	No	50	25
3	102 048	2	51 024	No	100	50
4	150 752	2	51 024	No	150	50
5	209 552	4	75 376	Yes	300	75
6	301 504	2 or 4	51 024	No	300	50
7	301 504	2 or 4	102 048	No	300	100
8	2998 560	8	1497 760	Yes	3 000	1 500
9	452 256	2 or 4	51 024	No	450	50
10	452 256	2 or 4	102 048	No	450	100

Note: DL-SCH = downlink shared channel, UL-SCH = uplink shared channel and TTI = Transmission Time Interval TTI and refers to the duration of a transmission on the radio link. The maximum data rates are rounded and are for fixed use. Category 8 UE supports the highest data rates (maximum number of CCs and 8 x 8 spatial multiplexing)[18].

2.2.4 Co-ordinated Multi-point Operation (CoMP)

Co-ordinated Multi-point is introduced in Release 11 to improve the network performance especially at the cell borders. It achieves this by providing the user equipment with connections to several base stations at the same time and using the one with the lowest loading to carry the data and so increase throughput. This requires that the base station (eNBs) dynamically co-ordinate to provide joint scheduling and transmissions as well as processing of the received signal and this means a UE may be served by 2 or more eNBs. This will be most relevant to cellular networks as Fixed Wireless Access user equipment will deploy directional antennas.

[18] It should be noted that these are theoretical maxima and unlikely to be achieved in practice due to MIMO path correlation etc. – we would expect actual speeds more likely to be 25-50% lower.

2.2.5 3.6 GHz Frequency Band in 3GPP

The 3.4 to 3.6 GHz bands (FDD and TDD mode)[19] and 3.6 to 3.8 GHz band (TDD mode) are identified as frequency bands for LTE-A in 3GPP technical specification for Release 12, ETSI TS 136 101 V 12.5.0 (2014-11).

Table 2-4: Operating frequency bands (Source: Table 5.5-1 in ETSI TS 136 101 V12.5)

Operating band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Mode
22	3410 – 3490 MHz	3510 – 3590 MHz	FDD
42	3400 – 3600 MHz	3400 – 3600 MHz	TDD
43	3600 – 3800 MHz	3600 – 3800 MHz	TDD

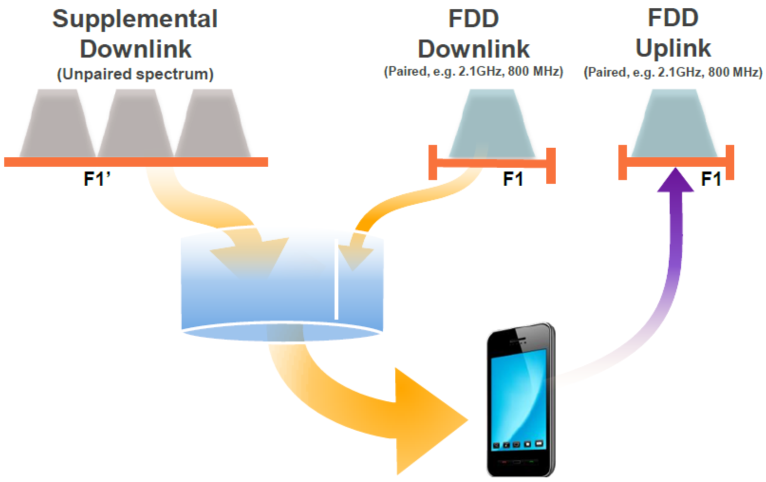
The 3.4 to 3.6 GHz band (TDD mode) is also identified for intra-band contiguous carrier aggregation[20] with band 1 (1920 – 1980 MHz / 2110 – 2170 MHz), band 19 (830 – 845 / 875 – 890 MHz) and band 41 (2496 – 2690 MHz).

This should mean that vendors will develop equipment (network and terminals) to support this frequency band and therefore it is more likely that equipment will become available in the short to medium term. See section 3.3.4 for further information on equipment availability.

[19] FDD (Frequency Division Duplex) is where separate channels are defined for the downlink and uplink with a set duplex separation between them. The frequency band is sub-divided into equal downlink and uplink channels. FDD is best suited for symmetric traffic.

In TDD (Time Division Duplex) the uplink is separated from the downlink by the allocation of different time slots in the same frequency band. This allows asymmetric uplink and downlink transmission which can change dynamically according to traffic requirements (e.g. could have a ratio of 3:1 if the downlink traffic is higher than the uplink traffic).

[20] In this instance the band is being proposed as a Supplemental Down Link (SDL) where there is asymmetric traffic to enhance the downlink capacity of another frequency band. This is shown in the figure below:



Source: Qualcom

2.2.6 Compliance with EC Decision

The studies undertaken within CEPT (e.g. ECC Reports 203 and CEPT Report 49) are based on technologies such as LTE-A and therefore equipment should meet the necessary technical requirements contained in EC Decision 2014/276/EU amending the Decision 208/411/EC..

2.3 WiMAX

2.3.1 Standardisation and deployments

WiMAX has been a key technology for the provision of both fixed and mobile services in the 2.3, 2.5 and 3.6 GHz bands using channel bandwidths of 3.5, 5, 7, 8.75 and 10 MHz. It is understood that the majority of commercial WiMAX deployments are based on un-paired TDD spectrum[21]. Whilst there have been a significant number of networks deployed[22] many are restricted to limited geographic areas (small towns, rural communities and businesses) and the majority are offering fixed services.

According to the WiMAX Forum there are around 25 commercial WiMAX Advanced networks world-wide with 3GPP TDD Band 42 (3400 – 3600 MHz) and Band 43 (3600 – 3800 MHz) being used in Australia, Europe, Latin America, North America and Russia.

The table below provides an overview of the more recent developments of the WiMAX standard:

Table 2-5: Overview of WiMAX Releases

Release	Date	Standard	Developments in the radio access network
1.0	2006 / 2007	802.16e	Based on 802.16e – 2005. OFDMA technology in UL and DL and enables UL and DL MIMO as well as beam forming. Defined for TDD mode of operation focusing on 5 and 10 MHz bandwidths in the 2.3, 2.5 and 3.5 GHz bands.
1.5	2008	802.16e Rev2	Initiated to enable mobile WiMAX in new spectrum including FDD bands
2.0	2010 / 2011	802.16m	Major enhancements to improve spectrum efficiency, OFDMA based.

WiMAX Release 2[23] (air interface defined in IEEE 802.16m) was recognised as meeting the requirements for IMT-Advanced of the ITU meeting the required peak data rates of 1 Gbps / 100 Mbps, for fixed / mobile users on the downlink. IEEE 802.16m base stations support interoperability with 802.16e systems[24] and 802.16m and 802.16e devices can interwork with the 802.16m base stations.

[21] See: "WiMAX Advanced: Deployment Scenarios based on input from WiMAX Operators and Vendors" from the WiMAX forum, TSC Approved (2014-09-14).

[22] WiMAX Forum claims more than 477 operators in 150 countries.

[23] Also known as WiMAX Advanced

[24] IEEE 802.16e was the basis of Mobile WiMAX or WiMAX R 1.0 and was recognised as 3G (IMT 2000) technology.

Channel bandwidths of 5, 10, 20 and 40 MHz and multi carrier aggregation is supported. MIMO is also supported which has a significant impact on performance.

2.3.2 Harmonisation of Standards for IMT Advanced

In October 2012 the WiMAX Forum announced that it would address harmonisation of standards within IMT Advanced technologies and has proposed a network evolution path to support harmonisation and coexistence across multiple wireless broadband technologies within the WiMAX Advanced network. The aim was to allow "existing WiMAX operators to benefit from the co-existence of WiMAX and other IMT-2000 / IMT Advanced technologies" as it was recognised that WiMAX operators were interested in, or investing in, other radio access technologies.

WiMAX Advanced Release 2.2 had the goal of enabling "WiMAX/TD-LTE RAN deployment, in adjacent-channel and co-channel operation, by a single operator, using a common or partially-common core network". In April 2014 it was reported that the WiMAX Forum had published 8 WiMAX specifications and that one of its priorities was development of WiMAX Advanced recommended service profiles and the intention to publish "specific common use cases and recommendations for Service Providers seeking to transition from WiMAX to WiMAX Advanced (by utilizing 3GPP technologies)".

2.4 Roadmap for LTE / WiMAX

In the WiMAX Forum white paper on 4G trends[25], published in November 2013, information is provided on the licensed WiMAX operators, applicable frequency bands and technology plans. Examples from Europe, using the 3.5 GHz[26] band, are replicated below:

Table 2-6: WiMAX operators using 3.5 GHz bands in 2013 in Europe (Source: Heavy Reading[27] and WiMAX Forum)

Country	Operator	Technology Plans
Azerbaijan	Azqtel (Sazz)	WiMAX to TD-LTE
Belgium	b.lite Telecom BVBA	WiMAX to TD-LTE
Bulgaria	Max Telecom	WiMAX
France	Bollore Telecom	WiMAX to TD-LTE
Germany	Deutsche Breitband Dienste	WiMAX to TD-LTE
Ireland	**Imagine Communications**	**WiMAX to TD-LTE**
Italy	AFT-Linkem	WiMAX to TD-LTE

[25] See http://www.4gtrends.com/wp-content/uploads/2014/01/HR-WiMAX-Forum-White-Paper-11-2013-Approved-Draft.pdf

[26] 3.5 GHz is used in some instances to describe the 3.4 - 3.6 GHz band and is interchangeable with 3.6 GHz used by ComReg.

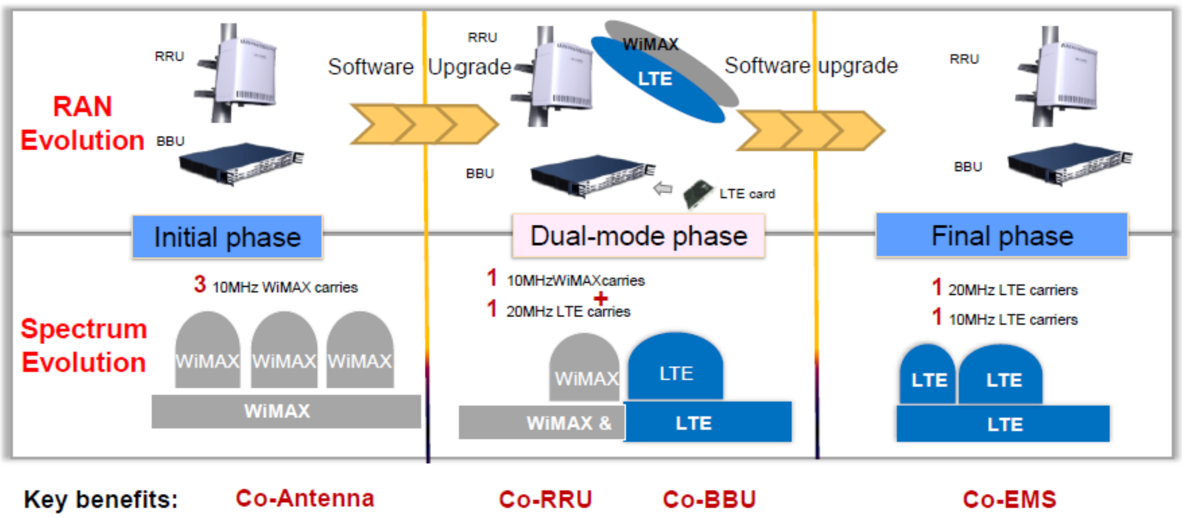
[27] White paper titled "WiMAX Advanced to Harmonise with TD-LTE in the 2.3, 2.5 & 3.5 GHz Bands Opportunities & Challenges for WiMAX2" available on WiMAX Forum at www.wimaxforum.org/literatureretrieve.aspx?id=197066

Country	Operator	Technology Plans
Poland	Netia, Milmex	WiMAX to TD-LTE
Russia	TransTeleCom, Enforta, Freshtel	WiMAX to TD-LTE
Spain	Neo-Sky, Iberbanda / Telefonica	WiMAX to TD-LTE
UK	UK Broadband	TD-LTE

A number of operators were already testing the migration from WiMAX to TD-LTE networks in 2013. It was also reported that Softbank, who recently acquired the Sprint TD-LTE network in the US, was "advising fixed WiMAX operators to deploy WiMAX Advanced networks in the major cities of each country supporting both fixed WiMAX and mobile TD-LTE utilising their existing licences[28]".

The figure below shows one of the options for evolution from WiMAX to LTE proposed by Huawei which uses a dual mode base band unit (BBU) that works with WiMAX and LTE TDD remote radio units (RRU) and so allows operators to take advantage of existing investments in sites, antennas and management systems.

Figure 2-4: Evolution path from WiMAX to LTE (Source: Huawei)



This appears to indicate that there is a general trend of migration away from WiMAX to LTE.

2.4.1 Compliance with EC Decision

The studies undertaken within CEPT (e.g. ECC Report 203 and CEPT Report 49) are based on technologies such as WiMAX Advanced and therefore equipment should meet the necessary technical requirements contained in the EC Decision 2014/276/EU amending the Decision 2008/411/EC.

[28] White paper titled "WiMAX Advanced to Harmonise with TD-LTE in the 2.3, 2.5 & 3.5 GHz Bands Opportunities & Challenges for WiMAX2" available on WiMAX Forum at www.wimaxforum.org/literatureretrieve.aspx?id=197066

2.5 Other Technologies currently used to provide FWALA services in Ireland

LTE-A and WiMAX Advanced are the only two technologies considered to meet the ITU IMT-A requirements.

There is currently a range of equipment / technologies that are deployed to provide Fixed Wireless Access in the 3410 – 3800 MHz band. These include DOCSIS Wireless and WiMAX 802.16, (e.g. 802.16-2004 and 802.16d). The majority of the WiMAX deployments are based on unpaired (TDD) mode whereas DOCSIS requires paired (FDD) spectrum.

Based on the responses from seven of the current FWALA operators[29] there are a significant number of the base stations installed using WiMAX technology[30].

The other technology currently in use is based on DOCSIS which supports the addition of high bandwidth data transfer to an existing cable TV system. DOCSIS 2.0[31] can be used over microwave frequencies, such as 3.6 GHz, using dedicated wireless links instead of a Hybrid Fibre Coaxial (HFC) network. The customer's cable modem is connected to an antenna box which converts the frequencies from the modem into the necessary uplink and downlink 3.6 GHz frequencies. Each customer is provided with a dedicated wireless link. In Europe the equipment is based on 8 MHz channels in a 25 MHz band[32]. The equipment is FDD and requires a 100 MHz duplex spacing.

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[29] eirCOM, Fastcom, Imagine, Lighthouse, permaNET, Viatel and Ripplecom.

[30] Over 90% based on the information provided by the seven FWALA operators

[31] Also DOCSIS 3.0 which is the more recent standard and supports increased UL and DL transmission bandwidth and support for IPv6.

[32] See http://www.hsdatasolutions.com/HSDS1/Products/Entries/2008/11/24_Reflections_on_the_lake_files/DB3000_DataSheetNew.pdf

3 3.6 GHz band developments in European and Global market

3.1 Channelling arrangements

In previous EC decisions regarding the 3.6 GHz band, no clear channel arrangement preference had been set out i.e. FDD or TDD.

In Europe EC Decision 2014/276/EU states that:

- "The preferred duplex mode of operation in the 3 400-3 600 MHz sub-band shall be Time Division Duplex (TDD).
- Member States may alternatively implement Frequency Division Duplex (FDD) mode of operation in the 3 400-3 600 MHz sub-band for the purpose of[33]:

  (a) ensuring greater efficiency of spectrum use, such as when sharing with existing rights of use during a co-existence period or implementing market-based spectrum management; or

  (b) protecting existing uses or avoiding interference; or

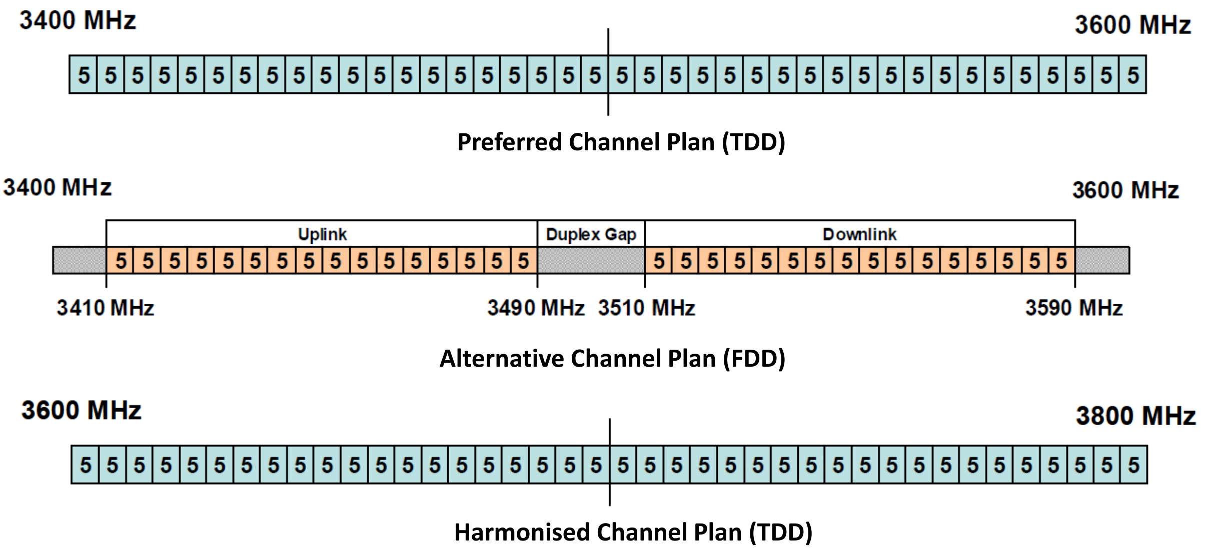
  (c) coordination with non-EU countries. Where the FDD mode of operation is implemented, the duplex spacing shall be 100 MHz with terminal station transmission (FDD uplink) located in the lower part of the band starting at 3 410 MHz and finishing at 3 490 MHz and base station transmission (FDD downlink) located in the upper part of the band starting at 3 510 MHz and finishing at 3 590 MHz
- The duplex mode of operation in the 3 600-3 800 MHz sub-band shall be Time Division Duplex."

The channel plans described in the EC Decision for the 3400 – 3800 MHz bands are provided in ECC Decision (11)06 as amended in March 2014[34]. These bands can support high data rate mobile / fixed communication networks using systems such as IMT-2000 and IMT-Advanced.

[33] In ComReg consultative document 14/101 in respect of the channel plans "ComReg notes that none of those purposes are particularly applicable in the Irish context and so is minded to make the entire band available on a TDD basis".

[34] The band plans are consistent with EC Decision 2014/276/EU

Figure 3-1: Channel Plans[35]



It was also noted in the responses to the ComReg consultation that the 3600 – 3800 MHz band could also be used to provide a supplemental down-link (SDL) to another frequency band[36].

3.2 WRC-15 and Global harmonisation

The 3.6 GHz band is one of the candidate bands being considered under the World Radio Conference 2015 (WRC-15) agenda item 1.1[37].

In Europe there is support within CEPT for both the 3.4 – 3.6 GHz and 3.6 – 3.8 GHz bands to be used by IMT systems. The draft European Common Proposals (ECPs) are proposing that "an identification for IMT in the band 3 400 - 3 600 MHz would maximize the benefits of harmonization[38], while providing administrations with full flexibility to utilize all or portions of this range for IMT, consistent with their national requirements". Similarly it is proposed that the band 3600-3800 MHz, which is already allocated to the mobile service on a primary basis in Regions 2 and 3, should be identified for IMT to achieve global harmonisation.

[35] Source: ECC Decision (11)06

[36] A SDL is configured in unpaired (TDD) frequency bands and is used to enhance the downlink capacity of another band using carrier aggregation.

[37] The spectrum was accepted for IMT (International Mobile Telecommunications) by many countries at WRC-07 with some obligations (cross-border deployments and power limitations) but there is currently no global allocation. WRC'15 agenda item 1.1 is "to consider additional spectrum allocations to the mobile service on a primary basis and identification of additional frequency bands for International Mobile Telecommunications (IMT) and related regulatory provisions, to facilitate the development of terrestrial mobile broadband applications, in accordance with Resolution 233 (WRC-12)". Under this item a number of frequency bands are being considered including 3400 – 4200 MHz.

[38] It was noted that the 3500 – 3600 MHz band is allocated to mobile service on a primary basis in Region 2 and 3 and also in some countries in these 2 Regions the band 3400 – 3500 MHz is allocated to the Mobile service on a primary basis through footnotes.

No other regional positions have been expressed clearly as yet but it is likely that there will be support for the 3.4 – 3.6 GHz band. The support for the 3.6 – 3.7 GHz / 3.7 – 3.8 GHz bands[39] is less clear.

For example the Australian regulator ACMA[40] has noted that "at the World Radiocommunications Conference in 2007 (WRC-07), over 100 countries identified all or part of the 3400–3600 MHz frequency range for IMT services.[41] The Australia preliminary view is to support seeking identification of the band 3400–3600 MHz for use by IMT under WRC-15 Agenda item 1.1."

In the US a FCC Notice of proposed Rulemaking and Order from December 2012 relating to the 3550 – 3650 MHz band[42] noted that at WRC-07 the 3400 – 3600 MHz band was identified for International Mobile Telecommunications (IMT) in much of Region 1 and eight areas in ITU Region 3.

It has also been reported that the Arab states[43], during a meeting of the Arab Spectrum Management Group, that there was seen to be "widespread support for a co-primary allocation of the lower C-band (3400 – 3600 MHz) but mixed support for IMT identification in other bands".

In the recent comments from the Global TD-LTE Initiative (GTI) to the South African Regulator's (ICASA) draft IMT road map[44] from October 2014 the following points were made:

Progress in Region 1: The GTI noted that "In Europe, there has been a transition from a framework designed for BWA/rural access to a new framework designed for IMT-Advanced purposes".

Progress in Region 3: The GTI noted that the regulators in Region 3 have sped up planning for the band[45]. Japan has studied the introduction of TD-LTE in the 3400 – 3600 MHz band and plans to launch LTE-A TDD commercial services around 2016. South Korea is also expected to release capacity in the 3.5 GHz band by 2018.

Progress in North America (Region 2): Here the GTI noted that the FCC is proposing to use 3.5 GHz as an innovation band. There would be a Three-Tier Spectrum Access – first tier incumbent access including authorised federal users, second tier priority access (e.g. critical users such as hospitals, utilities, government facilities and public safety and non-critical entities such as operators, and third tier General Authorised Access[46].

These initiatives could speed up the adoption of the 3.6 GHz band for IMT purposes worldwide.

[39] Impressions obtained from Conferences etc. by the Study Team. It is also noted that there have been discussions about a break point at 3.7 GHz. The concerns are based on the importance of the band for satellites.

[40] See ACMA consultation paper "Transitioning the 3.5 GHz band for future opportunities".

[41] The *Final Acts WRC-07* is available at www.google.com.au/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&cad=rja&ved=0CCwQFjAA&url=http%3A%2F%2Fwww.itu.int%2Fdms_pub%2Fitu-s%2Foth%2F02%2F01%2FS020100002C4006PDFE.pdf&ei=REVXUufrMKgMiQeK-IGAAQ&usg=AFQjCNHd4AyPDRv-XQugz3ebBt7LkwgSyA&bvm=bv.53899372,d.aGc.

[42] See paragraph 29 in https://apps.fcc.gov/edocs_public/attachmatch/FCC-12-148A1.pdf

[43] Report by Policy Tracker on March 13, 2015; "Arab states to support allocation of lower C-band to mobile".

[44] See http://www.ellipsis.co.za/wp-content/uploads/2014/08/GTI.pdf

[45] For example co-existence studies and field tests between TD-LTE and existing services such as microwave links and satellites.

[46] Under General Authorised Access have to accept interference from first and second tier users and not cause harmful interference to these licensees.

3.3 Spectrum awards

The majority of spectrum awards took place when the 3400 – 3600 MHz / 3600 – 3800 MHz bands were identified to provide wireless access on a national, regional or local basis. In a number of countries paired spectrum was licensed which could be used by either TDD or FDD technology. In general the bands were not of interest to the cellular operators who were concentrating on other, lower, frequencies where there was available equipment. A significant number of the licences were issued in the 2004 to 2008 period with the most recent awards being for any remaining frequencies.

For example in Austria[47] the initial licences were awarded in 2004 but there have been recent awards in 2013 and 2014 for limited frequencies and regions. Further information is provided in Appendix A.

A brief summary of the licensing status in each EU country is presented in the following table:

[47] See https://www.rtr.at/en/tk/FRQ_3500MHz_2009_AU/25633_Tender_Document_3_5_GHz_2009_w_o_annexes.pdf

Table 3-1: Status of 3.6 GHz bands in each EU Member State

Country	3400-3600 MHz	3600-3800 MHz
Austria	41 regional FDD licences, held by 10 licensees (no cellular operators), expiry 2019.	
Belgium	2 national licences (paired spectrum but may be used either for FDD or TDD). Licences expire 2019-2021. One of the networks (b.Lite) is offering LTE based services.	
Bulgaria	3 national licences (one FDD, two TDD). Two of the licensees also hold cellular mobile licences in lower bands. Licences expire 2015.	
Croatia	2 national FDD licences, both held by same licensee. Licences expire 2020. Currently providing WiMAX BWA service to c. 2,000 subscribers	
Cyprus	Exclusive satellite use	
Czech Republic	8 national licences held by 2 licensees, one of whom is also a cellular operator (Telefonica). Paired spectrum, may be used FDD or TDD.	
Denmark	One national licence currently, held by incumbent operator TDC. Licence expires 2024. A number of other licences have recently expired or lapsed. Paired spectrum, may be used either FDD or TDD	
Estonia	1 national and 6 regional licences, 3 licensees (no cellular operators). Unpaired spectrum.	5 national licenses, 3 licenses (same 3 as for lower band). Unpaired spectrum licenses.
Finland	39 regional licences held by 34 licensees, expiry 2016, paired spectrum (TDD/FDD). WiMAX technology. No cellular operators.	
France	c. 100 regional licences held by 15 licensees, including a number of local authorities. No cellular operators. Licences expire 2026. 1 national licence, expires 2018. Unpaired spectrum	
Germany	310 regional licences held by 16 licensees, due to expire 2020-2021. No cellular operators. Unpaired spectrum	
Greece	4 national licences, 4 licensees including incumbent fixed operator (OTE) and 1 cellular operator (WIND). Licences expire 2015-16. Paired spectrum, can be used FDD or TDD	

Country	3400-3600 MHz	3600-3800 MHz
Hungary	5 national licences held by 4 licensees, including cellular operator Magyar Telecom. Licences expire 2016. Paired spectrum (FDD or TDD)	
Italy	63 regional licences held by 12 licensees, including incumbent Telecom Italia. Licences expire 2023. Unpaired spectrum.	
Latvia	3 national licences, 3 licensees, including cellular operator Tele2. Licences expire 2018-2021. Paired spectrum (FDD/TDD).	3 regional licences, 3 licensees, expiring 2017-2025. 2 national licences, 2 licensees, expiring 2017-2020. Paired spectrum (FDD/TDD). No cellular operators
Lithuania	10 national licences, 2 licensees (no cellular operators), expiry 2022. Unpaired spectrum.	1 national and 1 regional licence, 2 licensees, expiry 2027. Unpaired spectrum.
Netherlands	Currently allocated for unplanned, uncoordinated fixed links (1 licensee)	
Poland	Various regional licences (details unavailable)	14 national licences, 3 licensees, expiry 2020, unpaired spectrum. 55 regional licences, 5 licensees, expiry 2020-2021, unpaired spectrum. No cellular operators.
Portugal	2 regional licences, 1 licensee, expires 2025, paired spectrum (FDD/TDD). 3rd licence held by incumbent PT expired 2014.	1 regional licence held by same licensee as lower band licences, expires 2025, paired spectrum (FDD/TDD)
Romania	There are now 4 licences held by Orange, Vodafone, UPC and 2K Telecom (Idilis). Paired spectrum. Plans to re-licence[48].	1 national licence held by Radiocom. Plans to re-licence with the 3410 – 3600 MHz band.
Slovakia	8 national licences held by 4 licensees, expiry 2015-2025. No cellular operators. Paired spectrum, may be used FDD or TDD. Further licensing underway in 2015 (2 licences for 8 x 5 MHz, FDD, TDD and 1 licence for 4 x 5 MHz TDD).	3 licences awarded each for 8 x 5 MHz (40 MHz) to O2 Slovakia, SWAN and BENESTRA in 2015
Slovenia	Information not available	
Spain	4 national licences, 4 operators, expiry 2020, paired spectrum (TDD/FDD). No cellular operators.	
Sweden	2 national licences held by cellular operators (Telia Sonera and Tele2), expiry 2017, paired spectrum (FDD/TDD). 292 regional licences held by 10 licensees (no cellular operators), expiry 2023, unpaired spectrum.	2,320 regional licences held by c. 40 licensees including 1 cellular operator (Telia Sonera)

[48] See https://www.telegeography.com/products/commsupdate/articles/2015/05/18/ancom-consults-on-upcoming-3-4ghz-3-8ghz-auction/

Country	3400-3600 MHz	3600-3800 MHz
UK	1 national licence, no expiry, paired spectrum (TD-LTE being deployed)	1 national licence, no expiry, paired spectrum (TD-LTE being deployed)

3.3.1 Recent awards for broadband deployments

There is little publicly available information regarding recent awards for broadband deployments that has been identified except for Belgium, Japan and Slovakia. Countries such as Bahrain, Canada and Spain where there is deployment of LTE TDD relate to previous spectrum licensing.

For example in Bahrain the Information Memorandum for the licensing of National Fixed Wireless Access licences was issued on 29 August 2006 and was for the award of 2 licences in the 3.5 GHz band (3410 – 3455 paired with 3500 – 3545 MHz and 3455 – 3500 paired with 3545 – 3590 MHz). The licences were for 15 years. The technical requirements were based on ECC Recommendation (04)05, "Guidelines for accommodation and assignment of multipoint fixed wireless systems in bands 3.4 – 3.6 GHz and 3.6 – 3.8 GHz". The successful licensees have since migrated to LTE technology.

Belgium

In Belgium the regulator, BIPT, issued a consultative document in November 2014[49] with responses due January 2015. It noted that the 3.4 to 3.6 GHz band had been authorised based on the Royal Decree of 24th March 2009 concerning the band 3410 – 3500 MHz / 3510 – 3600 MHz and licences had been allocated based on a FDD plan. A number of rights of use had been awarded by municipality and some had already been terminated. BIPT was proposing a number of amendments:

- The preferred frequency plan for 3400 – 3600 MHz to be TDD
- Allocate rights of use on a national basis
- 3600 – 3800 MHz should be assigned to ECS (Electronic Communication Systems)
- 3600 – 3800 MHz is for TDD operation
- Technical parameters as per Decision 2008/411/EC

It was also noted that the Royal Decree would need to be reviewed.

On 27 February BIPT issued a call for interested parties to apply for rights of use under the Royal Decree of 24th March 2009 in the bands 3410 - 3500 / 3510 - 3600 MHz and 10150 – 10300 / 10500 - 10650 MHz. There was a single applicant Citymesh SA who was awarded a licence for the band 3430 – 3450 / 3530 - 3550 MHz band for 10 years starting 7 May 2015 for 13 cities including, for example, Gent, Antwerp, Bruges and Brussels[50].

Canada

In Canada there have been 3 awards for the 2300 / 3500 MHz bands – the original was in 2004 followed by Phase 1 and Phase 2 for the remaining frequencies / areas in 2004 and 2009 respectively. It is noted that in respect of co-channel / adjacent area coordination the service providers in adjacent

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[49] See http://www.bipt.be/public/files/fr/21385/Consultatie_ECS_Spectrum-FR.pdf for the consultation document in French

[50] See http://www.bipt.be/public/files/fr/21498/Communication_Citymesh.pdf

areas were expected to develop their own mutually accepted sharing arrangements[51]. Since there has been a consultation undertaken by Industry Canada in August 2014 where they sought views on a number of proposals to enable both fixed and mobile services to operate in the 3.5 GHz band. It was proposed that geographically differentiated policy could be used for licensing the spectrum – in urban areas the band would be available for mobile services and in rural areas would remain for fixed services. After further consideration the policy decision was to allow flexible use throughout the band and remove the need to geographically distinguish between urban and rural areas. The existing FWA licensees would have a high expectation of obtaining licences provided they had met their licence conditions[52].

Japan

In July 2014 in Japan the MIC (Ministry of Internal Affairs and Communications) issued the 3.5 GHz Deployment Policy for LTE-A. This indicated that 40 MHz blocks would be licensed to 3 operators for TDD-LTE services to improve wireless coverage[53]. The goal is to achieve 1 Gbps of superfast wireless broadband using carrier aggregation with other frequencies. The spectrum was to be awarded by a “beauty contest”[54] and as part of the licensing requirements all of the operators would have to commit to a massive commercial deployment plan in 2016 using multi antenna technology (8 transmitters / 8 receivers). To avoid the need for guard bands between the operators the networks were to be synchronised but at the time the frame structure was still to be specified. The spectrum was awarded in December 2014[55] to SoftBank, DoCoMo and KDDI, all cellular operators, and the networks are expected to be commercialised by the end of 2016 covering 50 – 55% of mobile phone users in Japan.

Slovakia

Slovakia has recently auctioned 3 national licences, each of 8 x 5 MHz to support TDD, in the 3.6 to 3.8 GHz band for nomadic broadband and awarded 2 licences for 8 x 5 MHz to support TDD or FDD and 1 for 4 x 5 MHz for TDD in the 3.4 to 3.6 GHz band[56].

UK

In the UK Ofcom consulted on the terms of the requested variation to UK Broadband’s 3.6 GHz licence in June 2014 and proposed that the technical conditions should be aligned with those for the rest of the band when new licences are awarded through the PSSR (Public Sector Spectrum Release) auction.

[51] See the 2010 Consultation at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09488.html#t7_2

[52] See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10914.html

[53] See http://www.globaltelecomsbusiness.com/article/3376112/Is-Japan-opening-or-closing-the-doors-for-the-global-35GHz-industry.html#.VPX8LrlybIU

[54] Japan has not tended to use auctions for the award of spectrum.

[55] See http://www.gtigroup.org/news/ind/2014-12-25/5208.html

[56] See https://www.telegeography.com/products/commsupdate/articles/2015/02/05/three-firms-acquire-wireless-broadband-spectrum-in-slovakia/ 5 February 2015

3.3.2 Planned Spectrum Awards

Czech Republic

The Czech Republic Regulator, CTU, issued a consultation in March 2015 on draft conditions for the auction of the 3.7 GHz (3.6 – 3.8 GHz) band[57]. The frequency band is currently unused with fixed links use having ceased in 2011 and only two experimental licences being valid until May 15, 2015. It is considered that the band is suitable to provide high speed mobile electronic services throughout the country. Mention is also made to construction of broadband access networks and reducing the "digital divide" between rural and cities for high speed internet and the aim for at least one licensee to provide 30 Mbit/s (download) as a public service.

It is proposed to divide the band into five blocks each of un-paired 40 MHz with existing operators being limited to a single frequency block and new entrants to two frequency blocks (i.e. 80 MHz). The decision to award larger bandwidths than 5 MHz was based on the need to allow sufficient bandwidth for electronic communication services that would satisfy current and future needs of users.

There is the possibility of at least 3 nationwide radio networks plus one for a provider of wholesale services. The public communications networks in the 3.7 GHz band must comply in technical terms with the conditions set out in Commission Decision 2008/411/EC as amended by the Implementing Decision 2014/276 and in Decision ECC/DEC(11)06 . The equipment standard chosen must also comply with the conditions specified in ETSI standards or other related documents of the Commission, CEPT and ITU.

Moldova

In January 2015 the National Regulatory Agency for Electronic Communications and Information Technology (ANRCETI)[58] announced an auction of four 3400-3600 MHz licenses to be awarded for the provision of public electronic communications terrestrial mobile broadband wireless access and fixed access services. Each licence is for 50 MHz total bandwidth (10 x 5 MHz) and for 15 years duration. Interested stakeholders are to submit applications to participate by 13 March 2015.

In the special conditions for the licences, published on 30 December 2014 it says that the frequencies can be used exclusively to provide ECS (Electronic Communication Services), mobile terrestrial cellular radio access and broadband fixed wireless. The general technical access requirements are to meet the provisions of the following decisions and recommendations and reports of ITU / CEPT /ECC:

- CEPT Decision ECC / DEC(11)06
- CEPT Decision ECC / DEC(07)02
- CEPT Recommendation ECC / REC(04)05
- CEPT Report 19, and
- EC Decision 2014/276/EU of 5.02.14 amending Decision 2008/411/EC.

Specific mention is made of the BEM (block edge masks) specified in the EC Decision 2014/276/EU.

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[57] See http://www.ctu.cz/cs/download/aktualni_informace/vyhlaseni_vyberoveho_rizeni_05_03_2015.pdf for the consultation document in Czech

[58] See http://en.anrceti.md/ and http://www.anrceti.md/concurs_19012015

Romania

The Romanian regulator, ANCOM, issued a public consultation on the procedures for licensing of the 3410 – 3600 MHz and 3600 – 3800 MHz bands[59] in May 2015 with a closing date for submissions of 4 June. It is specified that the rights of use will be in accordance with the implementing Decision of the European Commission 2014/276/EU and the amending Decision 2008/411/EC.

It is proposed to award 16 paired 5 MHz blocks in the 3410 – 3600 MHz band and 36 unpaired 5 MHz blocks in the 3600 – 3800 MHz band. The licences will commence in January 2016 and have 10 years duration.

UK

The approach proposed in the UK could have implications in terms of cross-border considerations for the award of spectrum in Ireland and also may therefore inform ComReg's decision making process although it should be noted that Ofcom is proposing to award national licences, while we understand that ComReg has made no decision, as yet, as to whether to award national, or regional, licences.

Ofcom has undertaken a number of consultations in respect of spectrum awards in the 3.4 GHz bands. The most recent consultation that covered technical licensing issues was published on 7 November 2014 with a closing date of 23 January 2015[60]. Ofcom has since analysed the comments and published on 26 May 2015 a further document that includes their decisions on the technical issues and seeks stakeholder views on options for proceeding with the award of the 2.3 and 3.4 GHz frequency bands[61].

Ofcom is proposing to award 150 MHz of spectrum in the 3410 – 3480 and 3500 – 3580 MHz frequency ranges[62]. It is expected that the spectrum will be of interest to mobile network operators for providing additional capacity or for backhaul for small cells in other bands. Ofcom does not consider that the spectrum is "best suited for providing wide area coverage.

Ofcom, in their technical consultation from February 2014[63], made clear their intention to award spectrum in a way that is consistent with an un-paired TDD-compatible band plan. Also any award of the 3.4 GHz band has to be compliant with the EC Decision 2014/276/EU.

The technical points of note from the February consultation were:

- Licences will be for the whole of the UK
- There will be no type of service, technology or specific equipment requirements other than compliance with the 2014 EC Decision
- Usage might start immediately after the licences are issued (i.e. 2020 or later)
- Consultation respondents raised the possibility of the top part of the band having low cost equipment available because the US FCC is proposing to make 3550 – 3560 MHz available for small cells.

[59] See https://www.telegeography.com/products/commsupdate/articles/2015/05/18/ancom-consults-on-upcoming-3-4ghz-3-8ghz-auction/

[60] See http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz-auction-design/summary/2_3_and_3_4_GHz_award.pdf

[61] See http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz-auction-design/statement/statement.pdf which includes Ofcom's statement on technical licensing conditions and consults on the auction format.

[62] UK Broadband is already licensed for 40 MHz of spectrum in the ranges 3480 – 3500 and 3580 – 3600 MHz.

[63] See http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/summary/pssr.pdf

- Lot sizes of 5 MHz were proposed and this has not been changed as Ofcom want to enable maximum flexibility in terms of potential uses. Consultation respondents had previously indicated a range of preferred minimum spectrum holdings of 10 MHz, 20 MHz and 30 MHz.

In addition the consultation addresses the options for reducing the risk of interference at spectrum boundaries by:

- Higher performance filtering
- Intelligent scheduling of resources
- Careful location of transmitter sites, or
- Synchronisation of the networks.

Ofcom has decided, in respect of synchronisation between networks, to mandate traffic frame alignment but not identical frame structure to provide greater flexibility to the operators in terms of choosing the DL / UL configuration. However operators that adopt the preferred 3:1 configuration are allowed to use the synchronised mask[64] as defined in ECC Report 203 and those that adopt a different configuration will have to use the unsynchronised mask[65].

Further information is provided in Annex B.

United States

In the United States the FCC has adopted rules for commercial use of 150 MHz in the 3.5 GHz band (3550 – 3700 MHz). In the Report and Order published on April 21 2015[66] it was noted that this band being "particularly well-suited for mobile broadband employing small cell technology. A spectrum sharing plan for the 3550 – 3700 MHz band, known as the CBRS (Citizens Broadband Radio Service) plan, has been developed that will allow three classes of users; the current users which are mainly the Army and Navy radar systems and satellite equipment, unlicensed access providing the users buy an authorised mobile device and licensed service providers who would be provided some protection from interference from the unlicensed use.

The intention is to use a cloud-based Spectrum Access System to manage interference along with exclusion zones unless a service that could sense protected users nearby and automatically prevent interference could be developed.

The FCC has also opened a public consultation (notice) on the deployment of LTE-U (un-licensed LTE) / and LTE-LAA (Licensed Assisted Access) in the 3.5 and 5 GHz bands. It covers issues like details for commercial plans for pre-standard deployment of LTE-U / LAA and to what extent tests have been conducted on the impact of these technologies on incumbent users of unlicensed bands. Comments were to be submitted by 11 June.

3.3.3 Trials

In this section we consider current deployments in the 3.6 GHz band and any relevant trials to inform on how it is foreseen this band will be utilised and when on a world-wide basis.

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[64] Referred to as the permissive mask by Ofcom because it is less stringent

[65] Referred to as the restrictive mask by Ofcom

[66] See http://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db0421/FCC-15-47A1.pdf

In addition to trials associated with plans to roll-out LTE TDD by existing operators (see 3.3.4 below) in the US the National Telecommunications and Information Administration (NTIA[67]) has carried out tests to evaluate the potential for co-existence between LTE based small cells and radars. The results have indicated that using LSA (Licensed Shared Access)[68] it should be possible for LTE small cells and radars to share the same spectrum with minimal exclusion zones. NTIA has published two reports with the test results[69]. Qualcomm, Verizon, and Ericsson will be performing joint field tests in the 3.5 GHz band in 2015.

It has recently been reported that, in Australia, National Broadband Network (NBN) Co and Ericsson undertook a trial between two sites using a 20 MHz TDD carrier in the 3.5 GHz band[70]. It is understood that the Australian Government identified that NBN Co had insufficient spectrum[71] in outer metro areas and in August 2014 issued a declaration offering the 3.5 GHz band for the fixed wireless network. NBN Co has licences in around 41 locations in outer metro areas of Brisbane, Sydney and Melbourne for access to up to 200 MHz of spectrum in the 3400 – 3600 MHz band. Ericsson is reported as saying that the results [of the trial] "were promising and the 3.5 GHz TDD LTE ecosystem needs to be advanced to ensure the availability of devices[72] that use the spectrum".

In China, Ericsson has also undertaken trials with China Mobile of 3.5 GHz TDD LTE-A[73] in January 2015. The initial trials were carried out in Ericsson's laboratory in China and used carrier aggregation of 20 MHz of 2.6 GHz spectrum with 20 MHz of 3.5 GHz spectrum. This was followed by a field trial and it was concluded from the results of both trials that the 3.5 GHz TDD band can be used in the stand-alone mode or in aggregation with other (lower) spectrum bands.

3.3.4 Network evolution in 3.6 GHz spectrum

The WiMAX Forum white paper, authored by Heavy Reading in 2013[74], identified a number of operators that were seeking to evolve their existing WiMAX networks to LTE TDD to access a larger ecosystem of devices and for better user experience, (see Table 2-6). Below some further information is provided:

- UK Broadband conducted a TD-LTE pilot in 2012 and launched commercial service using 3.5/3.6 GHz spectrum in June 2012. They now have networks in London, Reading and Swindon and are planning to roll-out further in line with demand.
- Bolloré Telecom from France initially obtained regional licences to deploy a nationwide WiMAX network but they did not meet their roll-out obligations. The problem identified was lack of terminals planned by the major manufacturers (Samsung, Apple and RIM) and equipment vendors such as Alcatel-Lucent and Nokia Siemens Networks were moving away from WiMAX technology. Bolloré Telecom submitted plans to ARCEP, the French Regulator, to convert its

[67] The NTIA manages the US Government's spectrum including that used for Defence

[68] Licensed Shared Access is a viable way to share spectrum with existing non-mobile incumbent users that exhibit low or localised utilisation in their bands, and where it is undesirable to change the conditions of use within a reasonable time period.

[69] See NTIA announcement at http://www.ntia.doc.gov/blog/2014/new-technical-reports-evaluate-spectrum-sharing-35-ghz-band

[70] See http://www.cellular-news.com/story/Operators/67289.php

[71] NBN Co also have access to the 2.3 GHz spectrum

[72] The trials used network devices provided by NetComm Wireless.

[73] See http://www.waptrue.info/news/china-mobile-and-ericsson-complete-lte-a-tdd-trial-in-the-3-5ghz-band.html

[74] See http://resources.wimaxforum.org/resources/documents/marketing/whitepapers,

nationwide WiMAX network to TD-LTE using its 3.5GHz spectrum in Band 42 focusing on the top 15 urban areas reaching 24 million people and most of the smartphone users in France. In communications with ARCEP Bolloré[75] noted in their letter of November 2012 that they have not met their roll-out obligations and proposed a new roll-out plan with 3 phases (September 2015, December 2016 and December 2017).

- Imagine Group in Ireland has deployments across 240 MHz[76] of Band 42/43, originally offering WiMAX in all strategic parts of the country, but they have developed plans to launch TD-LTE[77].
- Neo Sky in Spain, originally a WiMAX operator, studied the introduction of a 3.5 GHz TD-LTE system and is now listed by the GSA as having commercially launched a network.
- Menatelecom, originally a WiMAX operator in Bahrain using an 802.16e WiMAX network built by Motorola in 2007, launched a LTE network in the 3.5 GHz band in September 2013 in tandem with its ongoing WiMAX network[78]. Menatelecom is now offering users a free LTE device in exchange for their old WiMAX devices.
- It has been reported that in the US Sprint (now owned by Softbank) plans "to kill off its implementation" of its "less-regarded" 4G technology, WiMAX"[79] in November 2015. The spectrum will be re-deployed to support LTE.

3.4 Equipment availability

3.4.1 End user devices

According to the GSA[80] in January 2015 there were 26 devices[81] available for the 3.6 GHz bands 42 and 43. In comparison with the other TDD LTE bands this is a small number as can be seen from the figure below:

[75] See the final Annex at http://www.arcep.fr/uploads/tx_gsavis/12-1314.pdf

[76] This 240 MHz is separated geographically due to the local area nature of the FWALA licensing scheme. Imagine currently has significantly less spectrum holdings at any specific location

[77] See http://www.eolasmagazine.ie/imagine-bringing-over-30mb-of-broadband-to-regional-and-rural-ireland/ and http://www.slideshare.net/zahidtg/overcoming-interference-challenges-when-migrating-from-wimax-to-lte

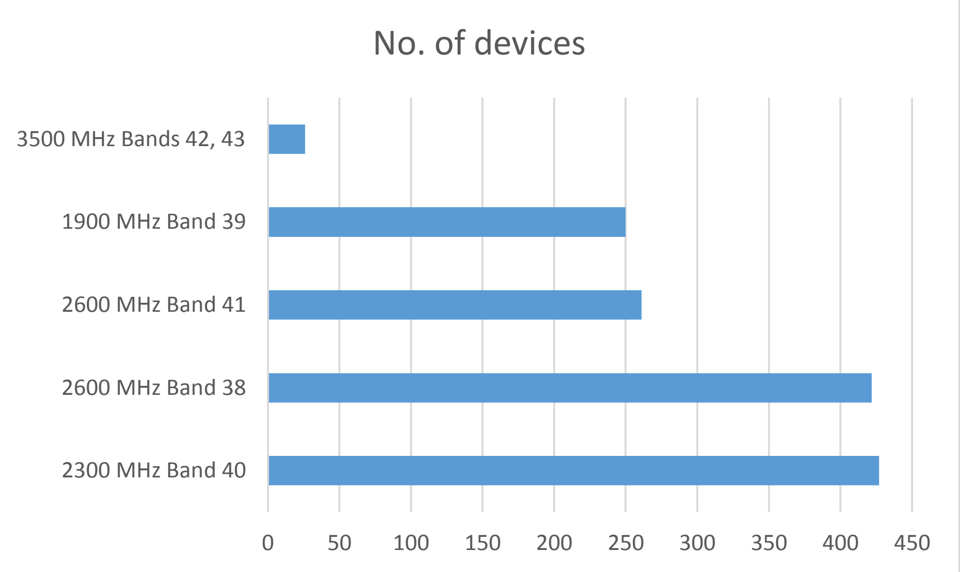
[78] See https://www.telegeography.com/products/commsupdate/articles/2013/09/20/batelco-zain-viva-awarded-additional-4g-spectrum-licences/

[79] See http://www.theregister.co.uk/2014/10/06/sprint_wimax_to_close_in_2015/

[80] Global mobile Suppliers Association. http://www.gsacom.com/downloads/pdf/Snapshot_LTE-TDD_extract_GSA_Evolution_to_LTE_report_070115.php4

[81] This number had not increased from the GSA report in October 2014

Figure 3-2: Comparison of number of devices available for TDD Frequency Bands (Source: GSA, January 2015)



The main form factor of the 3.6 GHz devices, from GSA data from October 2014, is routers with the remaining devices consisting of 3 femtocell equipments from Airspan, a mobile tablet and a module. The vendors of the routers include Greenpacket, Huawei, Jaton Technology, Mitrastar Corporation and Netcomm[82]. There is a mix of indoor and outdoor equipment.

Huawei demonstrated the first 3.6 GHz LTE-TDD smartphone during the 2014 Mobile World Congress (MWC) and it was expected to be available on the market in 2015.

According to Huawei chipsets that support LTE TDD in the 3.6 GHz band are available (e.g. chipset vendors that support this technology and frequency band include Huawei / Hisilicon, Sequans and Altair Semiconductor). Qualcomm's chipset availability depends on how the 3.6 GHz market will develop and likely future demand.

In a Study undertaken by Aegis Systems[83] and RTT into "Frequency Band Support for Future Mobile Handsets"[84], January 2014, it is commented that "Whatever happens, it seems unlikely that there will be any significant move away from the current focus on a limited number of regional core bands, albeit the number of these bands will increase over time (e.g. with the release of 600 MHz in the US and 700 MHz in Europe). Other non-core bands such as 3.6 GHz may well remain the preserve of more specialist applications such as dongles for the foreseeable future."

Impressions formed by the Study Team at the recent Mobile World Congress 2015 are that there are mixed messages as to when there will be a mass market for the 3.6 GHz band. Huawei were exhibiting a couple of 3.6 GHz router terminals for FWA and indicated the possibility of a smartphone with 3.6 GHz TDD capability in the next year – the previously trialled prototype smartphone is being re-designed to improve some aspects of the device. Qualcomm indicated they are interested in the

[82] See for example http://greenpacket.com/solution/duo/ and http://www.4gltemall.com/4g-wireless-router.html (in the latter see Huawei B2268 and B5268 Category 4 devices, Netcomm WNTD-4243 Outdoor TD-LTE Router Category 4)

[83] Plum Consulting London LLP and Aegis Systems Limited entered into an agreement in October 2014 under which the business operations of Aegis Systems became part of Plum.

[84] See http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2013/RF/Future_Mobile_Handset.pdf

band but no timescales provided and Ericsson are also talking about the band but appeared more focussed on other bands although they have been involved in recent trials in China (see Section 0).

It therefore seems unlikely, in the Study Team's view, that there will be any significant move to invest in equipment for the 3.6 GHz band in the near term and therefore the number of devices available will remain limited until there is sufficient demand due to increasing traffic, further harmonisation of the bands and spectrum award.

3.4.2 Network equipment

There is a similar situation in respect to the availability of network equipment. There are vendors, such as Airspan, offering integrated LTE multi-platform eNodeB equipment[85]. Other vendors of radio network equipment for TD-LTE at 3.6 GHz include Huawei, Nokia Siemens Networks (NSN), Datang Mobile and Accelleran[86]. Mitsibushi Electric Corporation announced in March 2015 that they had developed a Gallium Nitride High Mobility Electronic Transistor (GaN-HEMT) providing a power output of 100 W for macro-cells and 9 W for micro-cells in the frequency range 3.4 – 3.8 GHz with samples being released from April 2015[87]. The existing products mostly support macro and micro-cells but it is expected that pico / femto-cells will become available in a very short time frame as chipset vendors such as Qualcomm/Broadcom also have small cell reference designs that are nearly ready to work in 3.6GHz.

3.4.3 Industry views on mass market timescales

It is the Study Team's view that there are no clear views currently on when the 3.6 GHz band will become mass market. In the case of equipment for fixed networks the majority of the routers currently available are category 4 devices that will support up to 150 Mbps in the downlink and 50 Mbps in the uplink which relates to LTE Release 9.

Clearly the outcome of WRC-15 will have an influence as the bands 3400 – 3600 MHz and 3600 – 3800 MHz are being proposed for a co-primary allocation and IMT identification. The potential of a harmonised world wide band plan could provide economies of scale but there are specific

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[85] For example Air4G supports 3GPP LTE Release 9 and provides an upgrade path to LTE-Advanced and supports 2 x 2 MIMO, SU-MIMO and MU-MIMO. A TDD version is available that supports channel bandwidths between 1.4 MHz and 20 MHz. Another version of Air4G provides an integrated LTE and 4G WiMAX multiplatform base station. It also supports MIMO and channel bandwidths up to 20 MHz.

The maximum transmit power is 2 x +40 dBm and the equipment can support up to 64 QAM.

[86] News announcement May 2014. Accelleran is delighted to announce agreements to trial the M101 small cell with multiple network operators in the EMEA region. Jeff Land, VP Business Development said: "This success shows how attractive the M101 solution is in the LTE small cell marketplace and is an important step in bringing Accelleran's technology to market. "Accelleran's M101 is the industry's first optimized small cell designed for LTE and LTE-Advanced with the specific additional support for 3.5GHz and 1.9/2.1GHz TDD bands. Accelleran first developed the M101 at a time when few people appreciated the importance of TDD as an essential part of global LTE infrastructure. That foresight and the history of its team in delivering a number of industry "fi -
effective carrier grade mass volume solutions for 3.5GHz Small Cells.

[87] Mitsibushi indicated in their press release that as a result of the deployment of LTE and LTE-A networks the requirement for BTS that can offer increased data volume, smaller size and lower power consumption is increasing. See http://www.mitsubishielectric.com/news/2015/pdf/0311.pdf

considerations that might impact on the utility of the band such as sharing with incumbent fixed link and satellite services (which make extensive use of the band in some parts of the world).

In terms of Europe one respondent to the ComReg consultation suggested that mass market prospects for the band are likely to be in the middle term (around 2020) at European level and would be for pico and femto cells in mobile networks. The timing was considered to be in part due to the spectrum having been previously awarded "in many European countries for services that did not develop and so must be repurposed before mobile broadband services can be launched". The date of 2020 was also mentioned by one respondent to the Ofcom consultation.

In addition there are differing views on potential use of the band in Ireland which is likely to impact on timescales for network deployment. The 3.6 GHz band offers the potential for high capacity hot spot deployments for mobile operators due to the amount of bandwidth available and its propagation characteristics which make it suitable for deployment of pico and femto-cells. However currently there is a lack of mobile devices supporting this band. One respondent to the ComReg consultation was of the view that the band was suitable for continued use for fixed wireless access.

Similar views were expressed to the Ofcom consultation[88] with the band being identified as providing additional capacity to mobile operators with capacity pressures in other bands but also as being suitable for both high power and low power LTE users. There was also a proposal for un-licensed LTE.

On the basis of the wide mix of current uncertainties in respect of the likely applications that will be supported by the band globally (e.g. will the band be used for wide area fixed or small cell mobile applications or as a SDL for other bands) and also the uncertainty about the world wide allocation of the 3.6 to 3.8 GHz band for IMT it is likely that there will be limited new licensing of the 3.6 GHz bands initially with it potentially becoming deployed across Europe in around 2020.

[88] Source: Ofcom Consultation in April 2014 that referred to respondent's comments to the October 2013 consultation.

4 Equipment requirements for Ireland and implications for existing FWALA deployments

In the following sections we consider the implications of the proposed new licensing regime on existing FWALA deployments. Under the new licensing regime it is assumed that ComReg will implement the requirements of ECC Decision 2014/276/EU namely:

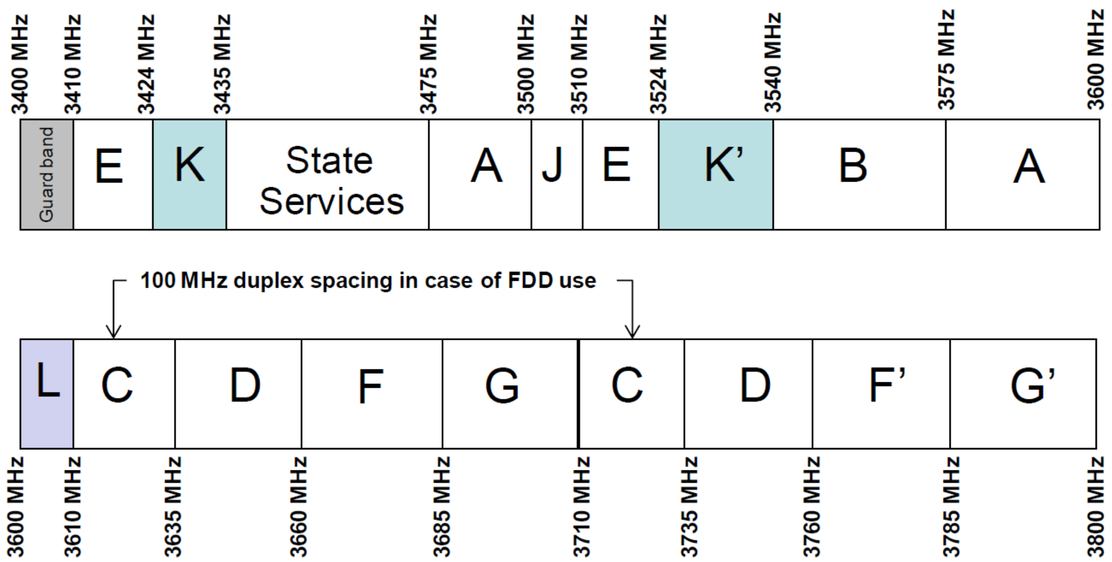
- TDD mode for 3600 – 3800 MHz
- TDD preferred for 3400 – 3600 MHz – ComReg has indicated its preliminary preference to adopt this mode of operation
- Assigned block sizes to be in multiples of 5 MHz
- Base stations and terminal stations shall be in compliance with specified Block Edge Masks.

These are considered in more detail in the following sections.

4.1 Channel Plans

The current channel plans are shown in Figure 4-1 below:

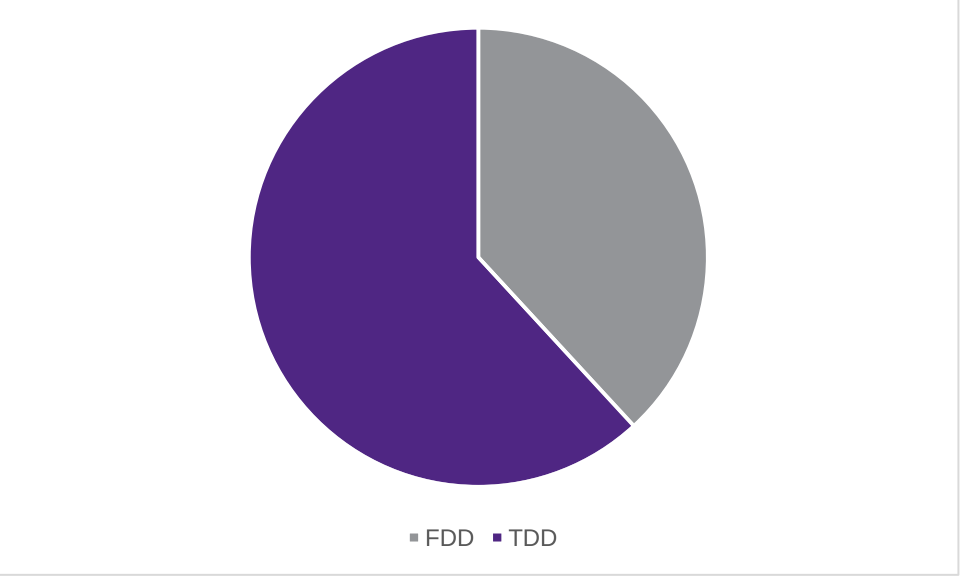
Figure 4-1: FWALA sub-bands in the 3.6 GHz frequency band[89]



It can be seen that in both the 3.4 – 3.6 GHz and 3.6 – 3.8 GHz bands there is currently a mix of FDD and TDD sub-bands and a new licensing approach based on TDD will impact on the operators that are using FDD mode equipment. Based on operator responses it appears that a significant number (6 out of 7 respondents) deploy FDD mode equipment or a mix of TDD and FDD equipment. However one of the respondents, Imagine, is already considering deploying TDD LTE–A.

89 Source: ComReg document 06/17R7, "Revised Guidelines for Applicants: FWALA Licences"

Figure 4-2: Comparison of number of base stations that use FDD or TDD



In the table below we consider the implications of the proposed use of 5 MHz TDD blocks in 3.4 to 3.8 GHz on the currently licensed sub-bands.

Table 4-1: Implications on currently assigned sub-bands of moving to TDD

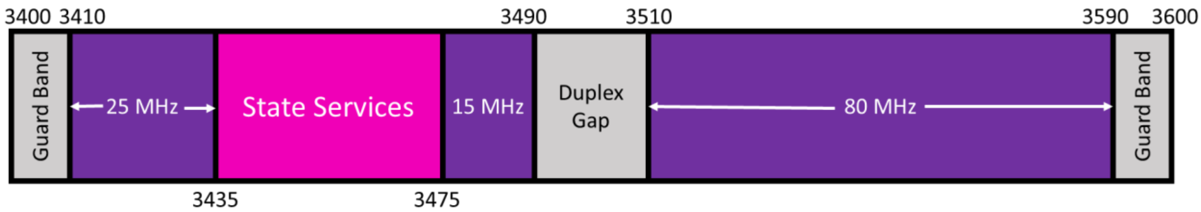
Sub-band	Frequencies (MHz)	Comment
A	3475 – 3500 / 3575 - 3600	Currently FDD. The frequencies would map on to the TDD channel plan providing a total of 50 MHz of non-contiguous spectrum.
B	3540 - 3575	Currently TDD. Matches the TDD channel plan and provides 35 MHz of spectrum.
C	3610 – 3635 / 3710 - 3735	Currently FDD. The frequencies would map on to the TDD channel plan providing a total of 50 MHz of non-contiguous spectrum.
D	3635 – 3660 / 3735 - 3760	Currently FDD. The frequencies would map on to the TDD channel plan providing a total of 50 MHz of non-contiguous spectrum.
E	3410 – 3424 / 3510 - 3524	Currently FDD. Apart from the lack of 1 MHz at the upper edges these sub-bands would map on to the TDD channel plan.
F	3660 – 3685 / 3760 - 3785	Currently FDD. The frequencies would map on to the TDD channel plan providing a total of 50 MHz of non-contiguous spectrum.
G	3685 – 3710 / 3785 - 3800	Currently FDD and TDD deployments. The frequencies would map on to the TDD channel plan providing a total of 40 MHz.
J	3500 - 3510	Currently TDD and maps on to TDD channel plan.

Sub-band	Frequencies (MHz)	Comment
K	3424 – 3435 / 3524 - 3540	Currently FDD. Apart for the additional 1 MHz at the lower edges these sub-bands would map on to the TDD channel plan.
L	3600 - 3610	Currently TDD and maps on to TDD channel plan.

Those existing operators using TDD and with access to sub-bands B, J and L should in theory be able to continue operation if they obtain access to the same blocks of frequencies in the same geographic areas. However it is noted that the currently installed equipment for Fixed Wireless Access may not be the ideal option for redeployment as due to its age and the developments in standards the equipment may have limited vendor support. (For example vendors are now offering WiMAX equipment that has a defined roadmap and equipment that meets 802.16d standards has been replaced with 802.16e and 802.16m).

However those FWALA operators deploying FDD in the 3.6 to 3.8 GHz band will only be able to continue operation, without significant investment, if the 3.4 to 3.6 GHz band is licensed for FDD mode. However in this band, with the existing State Services, only 1 block of 2 x 25 MHz and 1 of 2 x 15 MHz will be available assuming there are no guard bands required between the services as show in the figure below:

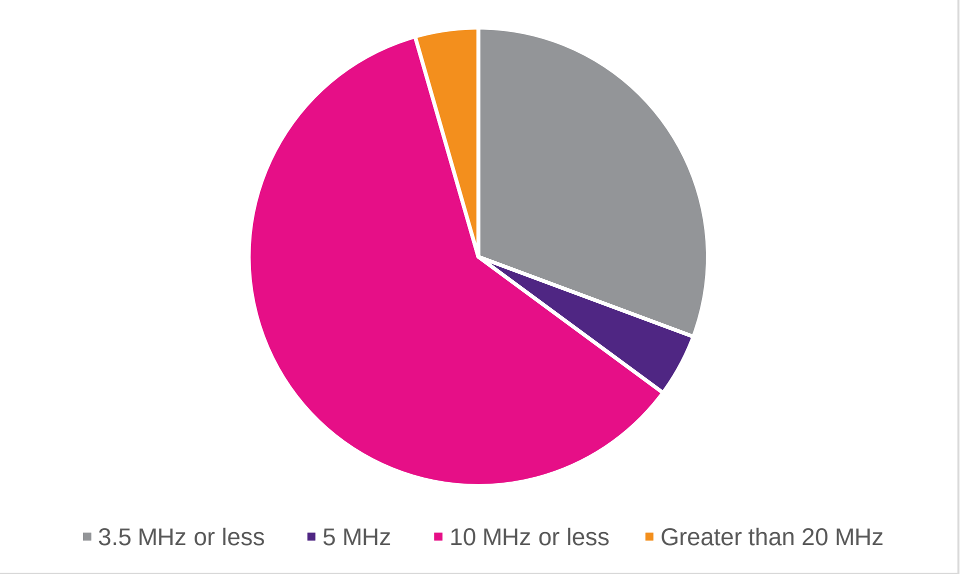
Figure 4-3: Implications for spectrum availability using FDD channel plan in 3.4 – 3.6 GHz band



4.2 Block sizes

The current transmission bandwidths deployed vary considerably as shown in the figure below.

Figure 4-4: Comparison of current transmission bandwidths



It can be seen that there are a number of base stations using bandwidths of 3.5 MHz or less. Whilst they could be deployed in 5 MHz blocks this might not be the most spectrally efficient solution. The largest proportion of base stations have a bandwidth of 10 MHz or less (but more than 5 MHz) with the majority in this group requiring 10 MHz. There are some base stations using significantly more than 10 MHz bandwidth.

At the time of licensing FWALA the applicable channel arrangements for point to multipoint systems in the 3.4 to 3.6 GHz band would have been defined in CEPT/ERC REC 14-03[90] and would have been based on multiples of 0.25 MHz, with possible duplex spacing of 50 and 100 MHz, but also rasters based on multiples of 1.75 MHz were available. This means a number of systems may not be compatible with the channel arrangements that would result from the use of 5 MHz block allocations and this could lead to inefficient use of the spectrum. For example a 3.5 MHz channel may need to be accommodated in a 5 MHz block or a 7 MHz channel in a 10 MHz block.

4.3 Compliance with EC Decision

Block edge masks are currently applicable for FWALA deployments – see ECC Rec(04)05[91]. These block edge masks differ from the current proposals but it is expected that the existing equipment used to provide FWALA services can meet the latest requirements assuming that it is possible to use an internalised guard band between the in-block and out-of-block emissions, if necessary. However again this may not be the most spectrally efficient solution.

[90] See http://www.erodocdb.dk/Docs/doc98/official/pdf/REC1403E.PDF

[91] See http://www.erodocdb.dk/Docs/doc98/official/pdf/Rec0405.pdf

4.4 Other considerations

It is noted that at least one of the current FWALA operators, Imagine, has expressed interest in migrating from WiMAX to TDD LTE-A. This would allow them to deploy equipment in compliance with the EC Decision 2014/276/EU amending the Decision 2008/411/EC and offer higher data rates (30 to 100 Mbps), advanced wireless broadband services, to their users.

Another consideration is the possibly of requiring synchronisation between operators. However this may be challenging as there is a mix of different uplink / downlink ratios amongst those existing operators using TDD equipment ranging between 8:1, 70: 30 and 3:1.

5 Conclusions

There are a number of potential applications for the 3.6 GHz band:

i. Small cell mobile network
ii. Small cell high bandwidth mobile network
iii. Supplementary down-link for other frequency bands to support high bandwidth mobile services
iv. Fixed wireless broadband network
v. Fixed wireless broadband network using standards / technologies that support advanced (high capacity) services

The range of potential applications underlines the difficulty of determining likely roll-out timelines and this is further complicated by the current lack of harmonised allocations, on a world-wide basis, for mobile services in the 3.4 to 3.8 GHz range and particularly the 3.6 to 3.8 GHz band.

To date, the deployment of macro cells operating in lower frequency bands has been the main emphasis of mobile network operators' rollout but at some stage there will be a need to enhance capacity, especially in urban areas, and higher frequency bands such as 3.6 GHz will be attractive because of the interference environment[92]. However there are still a number of alternative frequency bands available or coming available in Europe to meet such requirements so there is unlikely to be pressure in the short term to deploy services in another frequency band. In responses to Ofcom's consultations indications were that usage might start from 2020 or later.

There is also increasing interest in identifying frequencies to act as supplementary down-links and respondents to both ComReg's and Ofcom's consultations have raised concerns that any new licensing regime for 3.6 GHz in the UK should not impact on this option. This has implications for the use of synchronisation between networks to minimise interference between base stations.

In the case of fixed networks there is already equipment available that could be used and one of the existing FWALA operators, Imagine, is proposing to deploy TDD LTE-A. There are already some existing licensed WiMAX operators that have launched TD-LTE networks (see Section 3.3.4) although speeds may be limited depending on the category of user and network equipment available (the majority of the routers currently available are category 4 devices that will support up to 150 Mbps in the downlink and 50 Mbps in the uplink which relates to LTE Release 8 in a 20 MHz RF bandwidth). The redeployment of current TDD WiMAX equipment, whilst possible technically, does not appear to be an attractive option with the current trend of migrating to LTE and also because of the age of the equipment, the data speeds that can be supported, possible incompatibility with the block sizes and likelihood of inefficient spectrum use.

Higher data speeds of 3 Gbps in the downlink and 1.5 Gbps in the uplink will not be available until LTE Release 12 and the availability of category 8 UEs. Release 12 specification is due to be frozen in 2015 but there will still be further work required to define, for example, testing. It is therefore not anticipated that there will be equipment available until around 2018 and that will still depend on interest in the frequency bands. Therefore we tend to agree with the view that widespread network deployment is most likely to start around 2020 to support such high speed services. An earlier date

[92] The higher frequencies will transmit over shorter distances because of the propagation characteristics and so interference distances will be less.

would be possible for FWALA operators that want to migrate from WiMAX to LTE TDD and already have access to suitable sites and infrastructure and are willing to deploy earlier Release equipment[93].

[93] As noted in Section 2.2 LTE-A Release 10 meets the requirements of IMT Advanced and will support maximum data rates of 3 Gbps in the downlink and 1.5 Gbps in the uplink.

6 Glossary

ACLR	Adjacent Channel leakage Ratio
AMC	Adaptive modulation and coding
CPE	Customer Premises Equipment
CQI	Channel Quality Indicator
BEM	Block Edge Mask
BS	Base station
BWA	Broadband Wireless Access
CC	Component Carriers
CEPT	European Conference of Postal and Telecommunications Administrations
CoMP	Coordinated Multipoint
DAE	Digital Agenda for Europe
DL	Downlink
DOCSIS	Data Over Cable Service Interface Specification
DSL	Digital Subscriber Line
EC	European Commission
ECC	Electronic Communications Committee
ECC PT1	Electronic Communications Committee Project Team 1
ECC WG FM	Electronic Communications Committee Working Group Frequency Management
ECP	European Common Proposal
ECS	Electronic Communication Systems)
eiCIC	Enhanced inter-cell interference coordination
EIRP	Effective Isotropic Radiated Power
eMBMS	Evolved Multimedia Broadcast Multicast Service
eNB	Evolved Node B (LTE Base Station)

ERP	Effective Radiated Power
ETSI	European Telecommunications Standards Institute
EU	European Union
FDD	Frequency Division Duplex
FFS	For Further Study
FWA	Fixed Wireless Access
FWALA	Fixed Wireless Access Local Area
FTTC	Fibre to the cabinet
Gbps	Gigabits per second
GNSS	Global Navigation Satellite System
HeNB	Home evolved Node B (LTE Femtocell)
HetNet	Heterogeneous network (supports interaction between different types of cells and technologies)
HFC	Hybrid Fibre Coaxial (cable broadband technology)
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
IMT-A	International Mobile Telecommunications Advanced (4th generation mobile)
IMT-2000	International Mobile Telecommunications (ITU 3rd generation mobile standard)
IP	Internet Protocol
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union - Radiocommunications
I/N	Interference to Noise Ratio
LTE	Long Term Evolution (4th generation mobile technology standard)
LTE-A	LTE Advanced (latest version of the LTE standard)
LTE-LAA	Licensed Assisted Access LTE (version of the LTE standard)

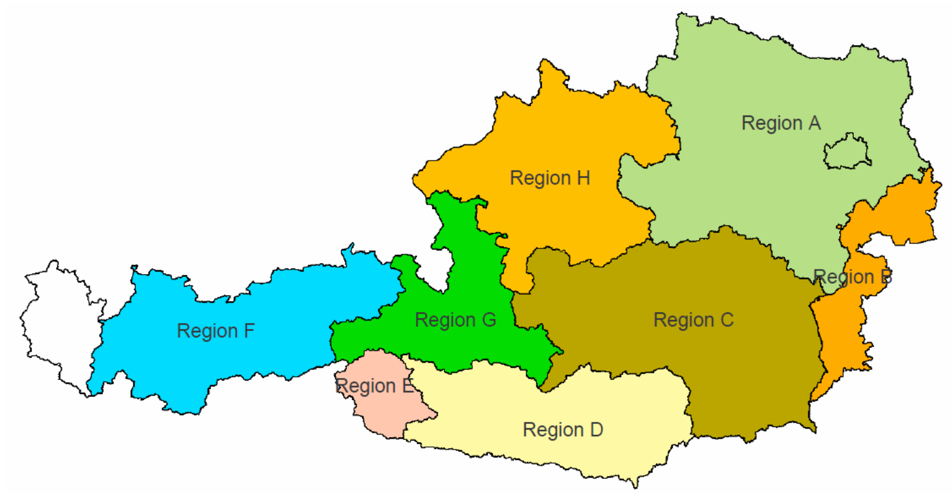
LTE-U	Unlicensed LTE (version of the LTE standard)
Mbps	Megabits per second
MCL	Minimum Coupling Loss
MIMO	Multiple Input Multiple Output
MFCN	Mobile Fixed Communications Networks
MoU	Memorandum of Understanding
NGA	Next Generation Access
NTIA	US National Telecommunications and Information Administration
OECD	Organisation for Economic Co-operation and Development
OFDMA	Orthogonal Frequency Division Multiple Access
PCI	Physical Layer Cell Identities
PSSR	Public Sector Spectrum Release (process for spectrum award in UK)
QAM	Quadrature Amplitude Modulation
RAN	Radio Access Network
RF	Radio Frequency
RRC	Radio Resource Control
SCFDMA	Single Carrier Frequency Division Multiple Access
SCH	Shared channel
SDL	Supplemental downlink
SRTM	Shuttle Radar Topography Mission
TDD	Time Division Duplex
TD-LTE	Time Division- Long Term Evolution
TD-SCDMA	Time Division – Synchronous Code Division Multiple Access
TTI	Transmission Time Interval
UE	User equipment

UL	Uplink
UT	User terminal
UTC	Coordinated Universal Time
VDSL	Very high speed digital subscriber line
WRC	World Radio Conference
WRC-15	World Radio Conference 2015
WiMAX	Wireless Microwave Access (wireless broadband technology)
3D	3 Dimensional
3GPP	3rd Generation Partnership Project (body responsible for LTE-A standards)

Appendix A: Regional licensing in Austria

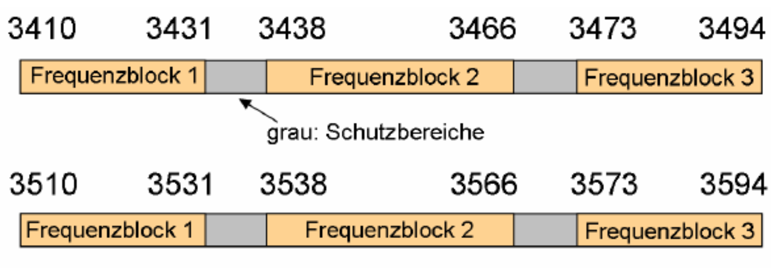
Regional licences were awarded in Austria based on the map shown below:

Figure A-1: Division of regions in Austria (Source: RTR)



The approach that was adopted in Austria for all awards was to identify 7 MHz guard blocks between the different frequency blocks with the possibility of these being used on the basis of agreement between the licence holders in the adjacent frequencies in each region.

Figure A-2: Frequency blocks for Austria (Source: RTR)



In addition RTR (the Austrian regulator) set a spectral power flux density (PFD) from a digital broadband wireless access system, where frequencies are allocated in an adjacent usage region, of -122 dBW/(MHz*m^2) in the adjacent region at a distance of 7.5 km from the border of the region for which the frequency was allocated. Also in the case of TDD operation it was stipulated that any loss of usable frequencies which arose due to larger than originally planned separations would be taken from the spectrum of the operator whose frequency use requires the additional guard distance in terms of frequency and geographic location.

Appendix B: Ofcom PSSR Award of the 2.3 GHz and 3.4 GHz Bands

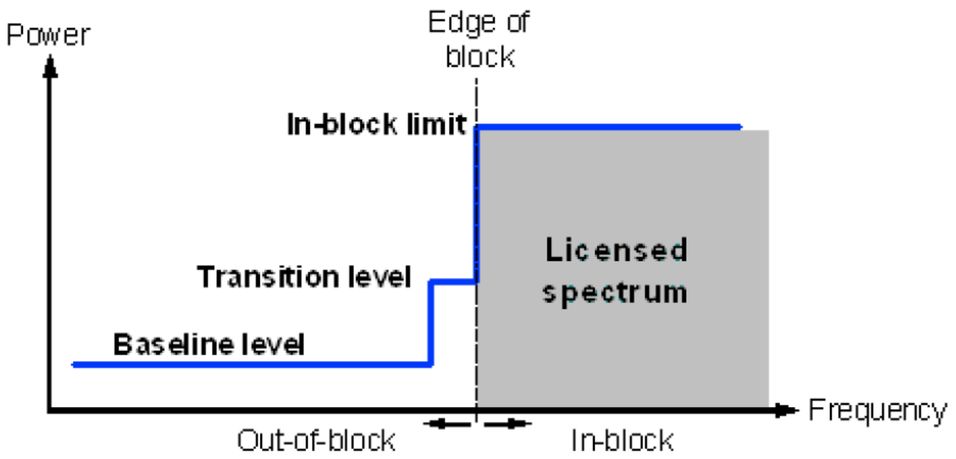
B.1.1 Ofcom Consultation on Technical Aspects of Licensing

The following summarises some of the technical aspects consulted on by Ofcom:

Proposals for block masks, transitional regions and synchronisation

Block Edge Masks (BEMs) are defined to enable co-existence between different uses / users operating in adjacent frequencies. The figure below shows the key elements of a BEM:

Figure B-1: Base Station Block Edge Mask Elements[94]



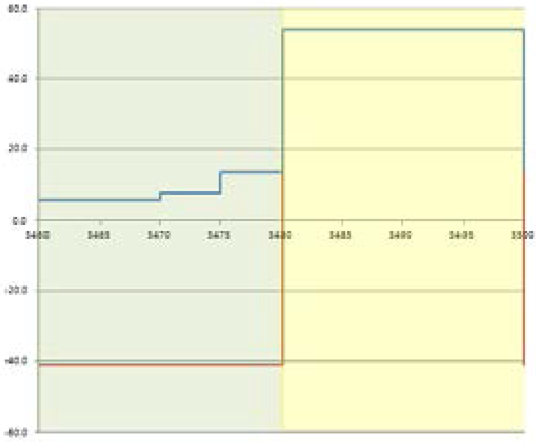
To enable co-existence among unsynchronised TDD base stations as well as defining the in-block and out-of-block power levels, proposed solutions include a frequency separation (i.e. guard band) between the edges of the two adjacent operators, the use of restricted blocks where EIRP is lower than the in-block limit in the upper and lower part of the contiguous blocks assigned to an operator and the use of internal guard bands agreed by the adjacent operators

Ofcom previously consulted in February 2014[95] on technical coexistence issues for the 2.3 and 3.4 GHz award and in this consultation an option (Option 3) of two out of block masks was proposed in the adjacent licensee's block. One was termed as the *permissive mask* (blue line in the figure below) used when there is a bilateral agreement such as where the networks are fully or partially synchronised and the other a *restrictive mask* (red line in the figure below). Basically the restrictive mask is described in ECC Report 203 for non-synchronised co-existence and the permissive mask for synchronised.

Figure B-2: Ofcom Options for Block edge Masks (Source: Ofcom)

[94] Source: ECC Report 203

[95] See http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/summary/pssr.pdf



These masks allow all assigned spectrum to be used at maximum power. The aim is to avoid the requirement for guard bands or restricted blocks and that if there was a need for any guard bands for transitional regions they would be internal (i.e. within a licensees frequency blocks). It was considered by a number of respondents[96] that avoidance of guard bands for transitional regions maximises spectrum efficiency.

Ofcom noted in their November 2014 consultation that synchronisation[97] between operators networks (i.e. where there is a set uplink / downlink ratio that is used by all operators) would be advantageous in maximising spectrum efficiency and reducing network rollout costs by avoiding the need for customised equipment. Two possible options were proposed to encourage or mandate synchronisation between networks operating in adjacent frequencies:

- Option 1: Traffic frame alignment is mandated but not identical frame structure. Licensees can use the permissive mask if they use the specified TD-LTE configuration or equivalent frame structure and comply with other parameters that would be specified in the Inter-Operator Synchronisation Procedure. If the restrictive mask is used it is not necessary to use the agreed frame structure.
- Option 2: Identical frame structures are mandated. This means all the licensees can use the permissive mask.

For both options Ofcom needed to specify the synchronisation procedure and provide details of the required parameters. An important consideration is the downlink / uplink ratio and Ofcom proposed to use 3:1 which is met by TD-LTE configuration 2 or an equivalent frame structure if a different technology is used (e.g. WiMAX).

In the Ofcom statement and consultation, published on 26 May 2015, the two options were discussed and Ofcom has noted “the desire of a number of operators for greater flexibility” and considers that it is “best left to the market to determine the most efficient use of spectrum”. On this basis Ofcom has

[96] Respondents to the February 2014 consultation including Huawei and UK Broadband and 2 confidential respondents.

[97] When the networks are synchronised this means that the base stations of the different licensees will transmit at the same time and the user terminals will also transmit at the same time, This is defined by the frame structure that is implemented. If there is no synchronisation then a high power base station could be transmitting in a sub-frame when a base station is trying to listen to a weak signal from a lower power user terminal or vice versa.

decided that there will be 2 frame structure options defined for the base stations defined in the licences:

- The Preferred Frame Structure, as shown below, where the TD-LTE frame configuration 2 (3:1), or equivalent for other technologies is used in conjunction with the Permissive (synchronised) Mask.

Figure B-3: Preferred Frame Structure (Source: Ofcom)

DL/UL ratio	Subframe number									
	0	1	2	3	4	5	6	7	8	9
3:1	D	S	U	D	D	D	S	U	D	D

- The Compatible Frame Structure, as shown below, such that all current TD-LTE frame configurations can be deployed as well those used by other technologies that meet the requirements. Those timeslots where there is no identified DL or UL or special sub frame can be used as necessary to meet the required DL/UL ratio. In this option it will be necessary to use the Restrictive (non-synchronised) Mask.

Figure B-4: Compatible Frame Structure (Source: Ofcom)

DL/UL ratio	Subframe number									
	0	1	2	3	4	5	6	7	8	9
Any	D	S	U							

In the case of small cells (operating at power levels not exceeding 24 dBm EIRP per carrier) Ofcom, based on responses to the February 2014 and November 2014Consultations has decided the following:

Table B-1: Synchronisation exemptions for small cells (not exceeding 24 dBm EIRP per carrier) (Source: Ofcom)

Environment	Decision
Indoor domestic	Exempted from requirements to align the frame and use any specified or preferred frame structure. May use permissive mask in all cases.
Other indoor locations	Initially as per indoor domestic. However if can demonstrate suffering from harmful interference then the small cells must comply with the inter-operator synchronisation procedure.

Environment	Decision
Outdoor	Regardless of transmitter power level must comply with requirements for frame structures and related masks as explained above.

Inter-Operation Synchronisation Procedures

Ofcom has decided, based on virtually all respondents to the consultations agreeing with their proposal, to mandate the Inter-Operator Synchronisation Procedure and compliance with the procedure will be part of the licence. It is accepted that operators may agree alternative arrangements and in such instances they require agreement from Ofcom so the licences can be varied accordingly. The list below provides the key parameters identified for synchronisation:

- A common phase clock reference for alignment of the start of the frame with UTC (Co-ordinated Universal Time)
- A compatible frame structure for use of the permissive (synchronised) mask. For TD-LTE use of configuration 2 (3:1 ratio) or an equivalent frame structure if a different technology is used.
- A compatible guard period
- Frame alignment (transmissions must comply with the defined frame structure for the first 3 sub-frames) for the restrictive mask
- Accuracy / performance constraints (aligned to the reference clock with an accuracy of +/- 1.5 µs
- Commitment not to interfere
- The terms and conditions where cross operator synchronisation may not apply / be required (e.g. indoor small cells)
- How to update the Procedure.

Proposals for power limits

The table below provides the proposed power limits for base stations:

Table B-2: Proposed power limits for base stations in 3.4 GHz band for TDD mode (Source: Ofcom)

Parameter	Power limit
In block power limit EIRP	65 dBm / 5 MHz (Femto cells up to and including 24 dBm and must use power control)
Out of block baseline power limit with permissive mask synchronised	Min(Pmax-43, 13) dBm / 5 MHz EIRP per antenna

Parameter	Power limit
Out of block baseline power limit with restrictive mask unsynchronised	-34 dBm / 5 MHz EIRP*
Transitional levels[98] applicable between -5 to 0 MHz offset from lower block edge, 0 to 5 MHz offset from upper block edge	Min(Pmax-40, 21) dBm / 5 MHz EIRP per antenna
Transitional levels applicable between -10 to -5 MHz offset from lower block edge, 5 to 10 MHz offset from upper block edge	Min(Pmax-43, 15) dBm / 5 MHz EIRP per antenna

* Maximum mean power relates to the EIRP of a specific piece of Radio Equipment irrespective of the number of transmit antennas

In the responses to the February 2014 Consultation[99] there were a range of views expressed in respect of synchronisation and these are briefly summarised in the section below. Similar arguments were provided in response to the November 2014 Consultation and are also included.

B.1.2 Summary of Responses to Ofcom Consultation on Technical Licence Conditions

There have been a range of differing industry views expressed in response to the Ofcom consultations in respect of encouraging or mandating synchronisation and these are briefly mentioned below:

Advantages / support for mandated synchronisation

One respondent supported mandating synchronisation using identical frame structures and use of the permissive mask (Option 2 in Ofcom's November 2014 consultation, para 9.50) as it achieves "the right balance of providing immediate certainty and future flexibility" and is essential to efficiently mitigate base to base and mobile to mobile harmful interference. They also proposed that synchronisation should be mandated for all cells irrespective of their dimension (macro to femto) as the protection distance calculated (Annex 10 of the November 2014 Ofcom Consultation) required a protection distance of 100 – 300 metres between an indoor femto base station and an outdoor macro base station to mitigate interference between them and would need to be even greater when aggregation of interference from multiple femto cells is considered

It was also noted by the same respondent that there are already examples where operators of TDD networks are synchronised:

- China where TDD operators in Bands 40 (2.3 GHz) and 41 (2.6 GHz) are synchronised based on TD-LTE frame configuration 2 (3:1 downlink / uplink ratio),
- Japan where the three licensees in Band 42 (3.4 – 3.6 GHz) intend to synchronise based on TD-LTE frame configuration 2.
- India where there were delays in roll-out until an agreement on a common synchronisation pattern was agreed.

Disadvantages / concerns about mandated synchronisation

[98] After 10 MHz the permissive baseline power levels apply.

[99] See http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz-auction-design/?showResponses=true

One respondent noted that whilst the use of synchronisation between operators can provide benefits in spectrum efficiency and ability to use equipment with less stringent filtering the approaches proposed might limit the use of the spectrum to the current 4G / LTE TDD mode rather than allowing more flexibility such as possible supplementary downlink mode (SDL) and future 5G technologies. This would be contrary to the aims of technology neutrality and suggested that Ofcom should, for example, allow operators the option to use an internal guard band where synchronisation with its neighbours is not feasible. It was noted in one response that there is a large quantity of spectrum available in the 3.4 GHz band and "it would be reasonable for an operator to set aside 5 MHz or 10 MHz for guard bands in order to have a free choice of frame structure"..

They also noted that the downlink/uplink LTE frame structure would be dependent on the business case and other considerations and a 3:1 ratio may not be appropriate. They noted that LTE configuration 2 is not the most efficient, because there are two special sub-frames per frame rather than one.

The respondent considered that neither of the two possible options for encouraging or mandating synchronisation were satisfactory. Of the two Option 1 was preferable as it provides the flexibility to use different frame structures although there is "the requirement to synchronise the start of each frame".

They also proposed that the award of 10 MHz blocks was more relevant than 5 MHz for high speed applications. However it was noted that if there was an alternative to use an internal 5 MHz internal guard band at one edge of the operator block instead of synchronisation between operators then there could be merit in using 5 MHz increments.

Another respondent, whilst recognising that full frame synchronisation has "superficial appeal in relation to minimisation of guard bands and less demanding equipment filtering", raised concerns that this would require all operators to adopt the same fixed uplink and downlink ratio and so negate the benefit of TDD in terms of adapting the uplink / downlink ratio to take account of changes in traffic patterns. Also spectrum efficiency may not be achieved if the mandated ratio does not match the traffic that is to be carried.

Concern was also raised that mandatory synchronisation could inhibit technological developments such as eIMTA (enhanced Interference Management & Traffic Adaptation) mechanisms which are being developed in Release 12 /13 of the 3GPP standard. Also the approach is not supportive of TDD as a supplemental downlink carrier.

They did support frame alignment to mitigate inter time slot interference caused by inter operator frame offset. They also consider that restrictive mask operation with a minimum of 5 MHz guard bands should be mandated in the auction as the default to prevent excessive interference between neighbouring systems and also proposes that masks should be harmonised at European level to ensure maximum economies of scale for equipment.

Similar views were raised by another respondent that believed "there are significant issues with both options" proposed by Ofcom for synchronisation and cited an example where an operator might wish to offer a service that has an asymmetry significantly different from the defined configuration. The alternative, in Option 1, where restrictive masks must be used if the operator uses any frame structure as having the potential for a number of operators to have relatively small allocations and having to dedicate some of this for guard bands. Concerns were also raised about inter-operator interference being caused by synchronisation failure (it was noted that for outdoor small cells it may be difficult to operate GPS synchronisation in many localities) or defined performance parameters not being sufficient.

They also proposed that the lot size should be larger and the restrictive masks mandated but no requirements for network synchronisation.

Another respondent expressed a strong preference not to mandate synchronisation between operators as it could restrict the possibility of modifying uplink / downlink ratios as products and services develop. Out of the two options for synchronisation proposed by Ofcom they expressed a preference for Option 2 as this would “allow the fastest deployment of networks …. and provide the best compromise in DL/UL performance”. It was proposed that LTE-A Configuration 2 (3:1 ratio) should be the default if operator’s could not reach agreement on the synchronised frame structure.

Other comments

Concerns were also input by another respondent that if there is a lack of synchronisation between networks poor out of band emissions from terminals, operating in the adjacent band, can be a major interference source when a device is located close to the adjacent band and communicating with a distant serving cell. They proposed that Ofcom should consider the 3.4 GHz band as a supplementary downlink (SDL) that could be used with 1.8 GHz and / or 2.1 GHz bands and licence it with a restrictive mask. However it should be noted that Ofcom’s decisions do not allow for use of the band as a supplementary downlink (SDL).

It was also proposed that a higher downlink ratio than provided by the proposed frame structure of LTE configuration 2 or equivalent (3:1) should be used.

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