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Plum Consulting's responses to the comments received from interested parties in response to ComReg consultation Document 15/70 on 3.6 GHz spectrum award

A report for ComReg.

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A report for ComReg

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Executive Summary

This document provides Plum Consulting's responses to the comments received from interested parties in response to ComReg's consultation Document 15/70, seeking comments on the release and award of the 3.6 GHz band and in particular the reports published alongside it as Documents 15/73 addressing co-existence recommendations, 15/74 rollout considerations and 15/75 spectrum requirements respectively.

The analysis of the responses in respect of Documents 15/73 and 15/74 have not led us to consider that any changes are required to either the content or the final conclusions. In respect of Document 15/75 we have made some changes and updated the report to take account of comments on inter-sector interference reducing the overall capacity at high loadings but this has not impacted on the results.

1 Introduction

This document reviews and responds to the comments received from interested parties in response to ComReg's consultation Document 15/70, in particular the reports published alongside it as Documents 15/73 addressing co-existence recommendations, 15/74 rollout considerations and 15/75 spectrum requirements respectively.

The aim of this "Response Document" is the provision of information, opinions and commentary to ComReg on the comments received in respect to the consultation. Specifically the following sections address comments received from:

Three Ireland (3IHL)

Aptus Ltd.

eircom Ltd. and Meteor Communications Ltd.

Imagine, and

Ripplecom

plum

2 TDD frame structure: Responses from Three Ireland (3IHL), Aptus Ltd, Imagine and Ripplecom

2.1 Responses

The responses from Three Ireland, Aptus Ltd. and Imagine that relate to the inputs from Plum Consulting are in respect of the Chapter 6 Question: "*a default TDD frame-structure based on TD-LTE configuration 2 (3:1) should be applied to incentivise inter-network synchronisation".*

3IHL's response says *"No, Three does not agree that ComReg should specify a TDD frame structure. This is incompatible with a service and technology neutral licence, and could prevent some legitimate use types."*

Aptus Ltd's response says *"Aptus believe that Synchronization should be encouraged but that are other synchronization solutions in the market place that operate equally if not more effective as TD-LTE and therefore should enough operators subscribe to a different synchronisation solution then that should be acceptable also. One example of this is Cambium Networks PMP450".*

Imagine's response *"agrees that synchronisation offers a practical measure to mitigate cross border interference and that higher permitted limits could be applied in the case of synchronised networks and as such a default TDD frame structure is necessary.*

However Imagine would prefer that in the first instance coordination procedures which would facilitate inter-operator coordination agreements should be used to avoid and manage such interference issues as these would permit higher limits to be applied to unsynchronised networks where these did not cause any interference issues.

Imagine agree that in TD-LTE the UL:DL Configuration 2 is the most commonly used configuration and therefore would be preferred as a default. However Imagine believe that this may not be the optimum configuration for networks that may be required in the future to meet the high 6Mbps targets for uplink specified in the NBP and that other UL:DL configurations such as Configuration #3(2:1) may be necessary in order to be compliant to the NBP uplink threshold. It should also be noted that within 3GPP there are ongoing developments and proposals for implementation of dynamic TDD ratio assignments in the future.

Imagine believes that to fully synchronise networks in addition to specifying the UL:DL configuration it is also necessary to agree many other parameters including, for example, the specific Special Sub-Frame configuration in order to achieve synchronisation. This is not referenced in either the ComReg document 15/70 or any of the three Plum reports (15/73, 15/74, 15/75), however a more comprehensive discussion of synchronisation measures is provided in the Ofcom reports – for example in Ofcom document "Public Sector Spectrum Release: Award of the 2.3 and 3.4 GHz spectrum bands, 7th November 2014", Figure 13: Proposals for key criteria in Inter-operator Synchronisation Procedure.

Imagine would support synchronisation provided such a full set of procedures, as described in the Ofcom document, were laid out and agreed and that sufficient flexibility remains for operators to choose alternative frame structures subject to certain conditions being met if these were required to meet for example uplink requirements of the NBP."

Ripplecom's response says *"While Ripplecom agrees in principle with encouraging inter-network synchronisation, we also feel strongly that nothing should be enforced that places non LTE solutions at a disadvantage to LTE based solutions. Allowance should also be made for customers (e.g. businesses) that may require synchronous services (i.e. equal DL and UL bandwidth".*

2.2 Plum response to comments

There is no proposed obligation from ComReg to synchronise networks (see paragraph 6.117 in the ComReg Document 15/70) but ComReg were of the preliminary view that they should put in place "*structures to encourage inter-network synchronisation. However at the same time the principles of service and technology neutrality should be maintained*". This can be achieved by:

- "*Not setting guard bands between assignments*"
- "*Setting a permissive BEM for synchronised networks and restrictive BEM for unsynchronised networks*"
- "*Setting a default frame structure*".

The approach proposed by ComReg is aligned with ECC Report 203 where the limits proposed are defined to optimise spectrum usage and avoid loss of network capacity by limiting interference between adjoining networks. There are 2 options for a licensee – to synchronise their network, including DL:UL ratio and use the permissive mask or not to synchronise and use the restrictive mask.

Ofcom has, after consultation, adopted a slightly different approach to ComReg's 15/70 proposal for the 3.4 GHz band[1], namely:

"*Traffic frame alignment is mandated but not identical frame structure". "Licensees can use the permissive mask if they are using the specified TD-LTE configuration or equivalent frame structure and are compliant with the other parameters in the Inter-operator Synchronisation Procedure. If they are not using the agreed frame structure they must use the restrictive mask. This means that it is possible to have two adjacent licensees operating on different frame structures, one with the permissive mask and one with the restricted mask*". This approach still allows licensees to utilise different DL:UL ratios using the restrictive mask.

The reason Ofcom requires inter-operator synchronisation is to align the start of the sub-frames and so reduce the potential for interference to adjacent licensees with a different TD-LTE configuration. The advantages are shown where two licensees are using identical configurations (in this instance configuration 2 with a DL:UL ratio of 3:1) and there is a single frame offset and without synchronisation there is the potential for 6 slot clashes where the uplink and downlink or the switch sub-frames, which can also provide additional downlink capacity, are not aligned. Ofcom also demonstrated that where the licensees adopt different configurations and there is an offset in the worst case there could be 10 clashes, as shown in the example of Licensee 1 using configuration 2 and Licensee 2 configuration 1 with a sub-frame offset, and this could increase the potential for interference and impact on the network capacity where this occurs. Therefore the use of synchronisation to align the start of the sub-frames would provide a significant improvement in the number of slot clashes.

[1] See: http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz-auction-design/statement/statement.pdf

Figure 2-1: Comparison of configuration and offsets

											Number of clashes
Licensee 1: Configuration 2	D	S	U	D	D	D	S	U	D	D	
Licensee 2: Configuration 2 (offset)	D	D	S	U	D	D	D	S	U	D	6
Licensee 1: Configuration 2	D	S	U	D	D	D	S	U	D	D	
Licensee 2: Configuration 1	D	S	U	U	D	D	S	U	U	D	2
Licensee 1: Configuration 2	D	S	U	D	D	D	S	U	D	D	
Licensee 2: Configuration 1 (offset)	D	D	S	U	U	D	D	S	U	U	8
Licensee 1: Configuration 2	D	S	U	D	D	D	S	U	D	D	
Licensee 2: Configuration 1 (offset)	U	D	D	S	U	U	D	D	S	U	10

Source: Ofcom

In the Real Wireless Report[2] they note that in general "*phase aligned time frames have superior performance [in terms of spectrum efficiency / capacity] in almost all of the scenarios studied with a few exceptions for particular cell locations*".

Inter operator synchronisation will automatically mean that the first 3 sub-frames are aligned when considering the configurations of the uplink and downlink time slots for the TD-LTE frame structures and this is a specific requirement detailed in Ofcom's inter-operator synchronisation procedure, Schedule 2, for the band. Other technologies are permitted provided that the requirements of the common first 3 sub-frames and 1ms time slot durations are met.

In the Real Wireless Report they also consider the practicality of synchronising two different operators' networks and conclude that all operators "*need to be able to maintain synchronisation between their base stations across their network*" and therefore it should be possible for different network operators to maintain phase synchronisation between their networks and proposed two possible approaches:

- "*Both networks synchronised to a common master clock time reference*"
- "*Two networks independently synchronised to their own master clocks with the masters delivering a common absolute time which is used as a phased timing phase reference in each network*".

It is important to recognise that Ofcom has identified, through discussions with stakeholders, that TD-LTE technology is the most likely technology to be deployed by licensees.

In ECC Report 216 it notes that when base stations use a different technology then it is necessary to analyse the feasibility of synchronisation on a case by case basis. The specific case of WiMAX/TD-LTE cross-technology synchronisation is considered in the ECC Report and it is concluded that "*most WiMAX 802.16e configurations have at least one equivalent TD-LTE set of parameters*".

[2] MC192 Assessment of Capacity Impacts with Various TD-LTE Block Configurations_v3.1docx, Issued to Ofcom, December 2013.

Further information is provided in an additional report from Plum, annexed to these responses on whether the requirement for a specific TDD frame configuration (option 2 with 3:1 downlink/uplink ratio) would adversely affect operators deploying non-LTE technology such as WiMAX and Cambium PMP 450[3]. It concludes that the latest implementations of the Cambium PMP 450 system include a 5 msec frame option that is compatible with WiMAX and, by implication, also compatible with TD-LTE systems providing an appropriate frame configuration is deployed.

So in summary to minimise adjacent channel interference and improve spectrum efficiency the key requirement is to ensure that the transmit and receive signals in the adjacent networks do not overlap – this can be done by having all the frames aligned, but can be also achieved with different frame structures (e.g. WiMAX or PMP 450), noting that a small amount of throughput is sacrificed (see Figure A-2, since the transmit and receive periods will have to be slightly shorter than for the LTE system to avoid any overlap). We would recommend using LTE TDD option 2 with SSF 6 as the default frame structure for synchronisation purposes as this has the shortest guard period and provides the highest downlink / uplink ratios for other technologies. It is recognised, however, that this might be a more constraining option for the other technologies to synchronise fully with (e.g. only one WiMAX frame configuration is compatible). The aim is to provide the option of a default frame structure that can be adopted by any licensee regardless of their intended technology. The downlink / uplink ratio of around 3:1 appears to be generally accepted by respondents, and industry globally as a reasonable compromise at this stage

Finally it should be noted that licensees still have the option of adopting different UL:DL ratios either initially or at a later date depending on the relative uplink to downlink traffic requirements of their customers and services. In such instances licensees will need to utilise the restrictive masks unless it is possible to agree with adjacent licensees to adopt a different configuration.

[3] Proprietary technology specifically mentioned by Aptus Ltd and Ripplecom in their responses

3 State Services: Response from Eircom Group (Meteor Mobile Communications Ltd and eircom Ltd)

3.1 Responses

The response from eircom relates to the need for a further study addressing whether State Services should have continued access to the band and if so what are the adjacent channel sharing constraints.

The response from eircom Group relates to ComReg's question on whether "*the band plan for the 3 400-3 600 MHz sub-band should be TDD (in line with the preference expressed in the 3.6 GHz EC Decision)*".

eircom's response says *"We note that part of the band 3 435 – 3 475 MHz is currently in use for unspecified State services and that ComReg is in ongoing discussions with the relevant State body. We believe it would be beneficial if all of the band could be made available without restriction. eircom requests that ComReg undertakes analysis that identifies the cost / benefit of the continued State use of this spectrum and that the outcome of this analysis be published alongside ComReg's final decision regarding this spectrum.*

If State services are to continue to be used then we would agree that the spectrum below the frequency of the State services should be released as a single 25 MHz block. eircom welcomes ComReg's commitment[1] to further clarify whether the existence of the State services may impact on the right of adjacent users to use spectrum won in the award process".

3.2 Plum response to comments

Plum has undertaken a separate study for ComReg that specifically examines the implications of the State Services remaining in the 3.6 GHz band in terms of adjacent band interference constraints. The outcome of this Study identified that adjacent band operation is possible in most scenarios for both the restricted and permissive block edge masks and with the mobile and fixed communications network equipment parameters largely based on EC Decision 2014/276/EU and ECC Report 203.

Considering the current use in the State Services band if in the unlikely case there should be occurrences of transient interference (random and temporary) then the use of additional filtering at MFCN base station receivers could be a potential solution as the results indicate that in-band interference from State Services transmitters overlapping the base station receiver out-of-band selectivity is the dominant interference mechanism.

In the other direction of potential interference it was found from the theoretical modelling that there is no significant difference when the synchronised or unsynchronised transmitter mask is used to represent out-of-band emissions from the base station transmitter because the receiver selectivity of the state services ground based receiver is the key parameter. In many cases, large margins are available in the link between the airborne transmitter and the associated ground based receiver terminal and this can be used to accommodate interference from MFCN base station transmitters located nearby into the State Services ground based receivers. It is possible to reduce further the potential for interference by reducing the MFCN base station EIRP and improving State Services equipment receiver selectivity. In certain deployment scenarios, the urban clutter effects and site engineering measures (e.g. shielding and antenna pointing) can play a role in reducing the interference potential further.

It was noted that with the current deployment of FWALA base stations in the adjacent band to State Services there have been no reported instances of interference and this is expected to be the same with the deployment of new networks following the award of the 3.6 GHz licences.

4 Document 15/75: Responses from Imagine and Ripplecom

4.1 Responses

The specific issues addressed in the responses from Imagine and Ripplecom in respect of Document 15/75 are:

- Assumptions used to assess spectrum requirements are based on a pessimistic view of the FWALA market.
- Inter-sector interference has not been accounted for in the calculations
- Report is strongly biased towards exclusive use of LTE-TDD technology
- Incorrect reference in the network planning section - it should be ITU-R P.1410-07

The detailed responses from the two respondents are provided below:

Imagine's response raised a number of comments in respect to Plum's report on spectrum requirements, Document15/75.

1. Pages 31 and 32 of Imagine's response:

   "Plum have assessed the spectrum requirements of a FWA network in three different environments (urban, suburban and rural) and have concluded that "a total of up to 80MHz would be required by a single network to cater for a future high speed wireless broadband service compatible with the DAE 30 Mbps target, based on current FWALA infrastructure density and market share (4% of the total broadband market). This estimate is also based on the assumption that there would be a single wireless operator in each area."

   This pessimistic view is driven by the inappropriate and inaccurate of the decline in use and demand for FWA dealt with earlier [sic]. Imagine in line with the NBP anticipate rolling out a higher capacity network using a minimum of 160MHz of spectrum In their analysis, Plum also consider the requirements of providing service to 50% of dwellings in rural Donegal, suggesting that "fixed wireless network configured to deliver coverage to all of the populated areas of Donegal, having access to 100MHz of spectrum and sufficient fibre backhaul capacity would be capable of serving up to half the population with a high speed broadband service." We note that both ComReg's own consultants (Plum) and Huawei note that FWA can be a competitive method of providing NGA services.

   Imagine's own analysis has found that a high capacity NGA FWA network to deliver much needed NGA services and to help achieve the NBP would benefit from use of more spectrum than suggested by Plum (100MHz) and would like to see ComReg consider making this a key consideration of the spectrum lots that are being considered. Imagine suggest that a minimum of 160MHz (rather than ComReg's suggested lower end of 150MHz) be set aside for Fixed NGA service delivery in appropriate lot given the likely use of 20MHz channels."

2. Page 44 of Imagine's response:

"In the Plum report 15-75, section 3.2.6 where they outline their approach to determining the sufficient amount of spectrum required to provide a reasonable level of service they first calculate a spectrum efficiency of 87Mbps / 20MHz = 4.35bps/Hz. Plum then go on to state the following: "LTE technology incorporates advanced scheduling and interference management capabilities that enable a single frequency re-use factor to be deployed, i.e. the same radio channels can be deployed on all base station sectors. This helps to maximise capacity and spectrum efficiency by enabling all an operator's available radio spectrum to be used at all locations in the network."

Whilst Imagine agree that the technical capability exists to enable single frequency re-use in LTE networks the difficulty with such an assumption is that in Plum's subsequent analysis where it appears that a single frequency reuse is assumed it fails to take proper account of the reduction in sector throughput that results from such a reuse configuration. Depending on the exact deployment conditions (e.g. cell density, terrain, etc.) the reduction in sector throughput from a single frequency reuse can range from 50% to 90%.

Imagine's own tests on TD-LTE have shown that sector throughput can reduce by up to 50% when an adjacent sector on the same frequency is introduced. Other studies have shown that throughput for a frequency reuse of 1 reduces cell capacity to 1/10th of its original capacity for example refer to Celplan document "4G Technologies Myths and Realities". By not taking this into account the Plum report significantly underestimates the amount of spectrum required to provide a reasonable level of service. The consequential impact may be an increase in capital expenditure which in marginal population density areas may make such investments uneconomic thus reducing the ability of the commercial sector to serve the largest number of customers without the requirement for state subvention.

Whilst the 87Mbps stated by Plum is broadly in line with Imagine's own estimation of an average throughput of a 20MHz sector (84Mbps), However, Imagine's figures are based on LTE-A deployed as a fixed wireless network and incorporates factors such as MIMO gain to achieve this figure. FWA involves many LoS paths so interference occurs over much bigger distances than in MBB, hence the need for proper reuse planning. It also requires the delivery of assured data rates under contention conditions which is not the case in MBB."

3. Pages 53 / 54 of Imagine's response:

"In the calculations made by Plum in section 3.2.6 of report 15/75 is 4.35bps/Hz achieved by delivering 87Mbps in a single 20MHz channel. However, in the Plum model no account is taken of the increase in interference when adding sectors and/or channels in an n=1 configuration. The effect of this would be that the capacity of each 20MHz channel and hence overall spectral efficiency would be significantly reduced when additional channels are introduced. In our estimate deploying an n=1 configuration using even 2 x 20MHz channels at the same frequency would at best give a total throughput of c84Mbps for the 2x20MHz configuration therefore giving a resulting spectral efficiency of only c2.1bps/Hz.

To achieve a target spectral efficiency of 4bps/Hz in a real world multiple site network would require that almost all users achieve the very top MCS levels of 64QAM as well as MIMO gain which is not consistent with the simple scenario described in the Plum report 15/75. Imagine's calculations of peak throughput, taking account of coding rates and overheads shows that *without MIMO the peak DL throughput achievable with the top MCS level 28 (64QAM) is 56Mbps showing that a throughput of 87Mbps quoted in the Plum report cannot be achieved without MIMO."*

Ripplecom provided two separate inputs to the consultation that relate to document 15/75 as follows:

1. "Comments on ComReg 15/75, LTE-A vs PMP 450" authored by N.J.R. King of Cambium Networks. This document *"computes the efficiency of LTE-A versus PMP 450 using the Plum Report as a basis"*. The document concludes that *"after correcting an error in the LTE-A analysis PMP450 is shown to have 30% greater spectral efficiency the LTE-A".* The error referred to relates to inter-sector interference assumptions and the impact on the number of users for the quad-sectored base station. It also comments in the network planning section that the reference is incorrect and should be ITU-R P.1410-07.
2. Submission to ComReg document 15/70 where in Section 4 Ripplecom provide a commentary on Plum's report 15/75 and refer to their two input documents above. They *"highlight the fact that the 15/75 document was highly biased towards LTE Advanced technology which flies in the face of the goal to ensure technology neutrality in the spectrum usage".*

   In response to Chapter 6 Consultation Question on "*whether the band should be released on a service- and technology- neutral basis*" Ripplecom again notes the report 15/75 is strongly biased towards exclusive use of LTE-TDD technology.

In addition they provided information on a Ripplecom NGA trial titled "Can Fixed Wireless deliver Next Generation Access speeds?". This is a stand-alone document reporting on trials undertaken in the area of Clonmel using a 20 MHz channel from 3610 – 3630 MHz with a centre frequency of 3620 MHz in the 3.6 GHz band and a 20 MHz channel at 5825 MHz in the 5 GHz band. It does not comment on the Plum reports.

4.2 Plum response to comments

Assumptions to assess possible spectrum requirements:

The aim of Section 4 of the report (document 15/75) was to provide an indication of the implications in terms of spectrum requirements of using a fixed wireless network to deliver high speed broadband at various locations in Ireland. Three different potential market scenarios were considered, namely:

- All households served by wireless broadband (this is extreme scenario and is included for reference purposes only)
- The current 4% share is maintained nationally
- The wireless market share increases but differs according to the extent of local competition – we have assumed a 10% share in large urban / suburban areas, 30% in smaller urban / suburban areas and 50% in rural areas.

The analysis also considers that there is only a single network that will meet the FWA demand so the spectrum required will be an over-estimate compared with there being 2 or 3 operators addressing the same market.

On the basis of the different market scenarios assumed and the assumption of a sole operator per geographic area Plum considers that we have provided a reasonable assessment of likely spectrum requirements over the longer term, taking account of anticipated further evolution of wireless technology[4].

Inter-sector interference:

Plum acknowledges that in a practical network deployment at high loading levels and assuming single frequency re-use with the same polarisation deployed throughout, inter-sector interference could lead to a significant reduction in available cell throughput. Depending on the distribution of users we would expect this to be up to the order of 50%. This would imply a corresponding increase either in the number of base stations or amount of spectrum required. The much higher reductions (e.g. in the referenced presentation by Celplan) appear to relate to a mobile environment where there is likely to be significantly greater cell edge interference due to the non-directional CPE antennas.

However, a number of other factors need to be taken into account in estimating the longer term requirement for FWA spectrum. For example:

- The assumed reduction in capacity takes no account of any polarisation discrimination that might exist between users in neighbouring cell sectors. Whilst this is reasonable in a mobile environment, in a fixed network based on line of sight or near line of sight propagation there is scope to make use of polarisation discrimination to reduce significantly the impact of inter-sector interference[5]. Alternatively both polarisations could be deployed to provide up to 100% MIMO gain.
- The LTE standards are continuing to evolve and the latest standards include provision for up to 256QAM modulation at the highest CQI levels providing a potential improvement of up to 33% in throughput.
- Under a high demand scenario, it is likely that in many locations multiple cell sites would be visible, providing a choice of base stations for individual CPE antennas to be aligned with and reducing the likelihood of individual subscribers being located at the edge of a sector.
- Availability of multiple carriers provides scope for fractional frequency re-use, i.e. usage of certain sub-carriers on a dynamic basis exploit in homogeneities in the loading. With carrier aggregation individual carriers may be dynamically re-assigned within the network to provide supplementary to cater for short term breaks in traffic at particular locations.
- Ongoing developments in smart antenna technologies such as adaptive beamforming are likely to yield further improvements in throughput under heavily loaded conditions.

Taking these factors into account, we consider that the capacity estimates presented in the report are likely to be representative of the longer term capability of advanced wireless networks, even allowing for the impact of inter-sector interference under high load conditions. We have however revised our calculations by assuming polarisation discrimination would be used to minimise inter-sector interference, hence reducing the scope for MIMO gain, but taking into account the future availability of 256QAM LTE systems.

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[4] *It is noted that Imagine's calculations focus on a single example and propose that a minimum of 160 MHz of spectrum would be required to allow for the roll-out of a cost effective network. Ripplecom however, using the example of a proprietary equipment, has estimated that significant percentages of the rural population can be served with considerably less than 100 MHz.*

[5] Such an approach is described, for example, in "Performance improvement of fixed wireless access networks by conjunction of dual polarization and time domain radio resource allocation technique" by Alexander Vavoulas et al of University of Athens, International Journal of Communication Systems, 2010, which suggests potential throughput improvements of up to 95%.

The net effect of these changes is to reduce the estimated average throughput spectrum efficiency by approximately 10 per cent from 87 Mbps / 20 MHz to 78 Mbps / 20 MHz (3.9 Mbps / Hz). As a rounded figure of 4 Mbps / Hz had been used in our previous spectrum requirement estimates the revised assumptions do not have any substantive impact on our conclusions in this regard.

The report has been updated to take into account these revised assumptions and the inter-cell interference issues.

Bias towards TD-LTE technology:

The focus on LTE-A in the report 15/75 is based on Plum's understanding that this standard is emerging as the preferred choice for many operators worldwide (for example already being deployed in the 3.6 GHz band in countries such as Belgium, Canada, Croatia, Japan, Slovakia, Spain and the UK), and that the standard presents a good example of "state of the art" advanced wireless technology. It is not intended to preclude alternative technologies, so long as these can meet the requirements for co-existing with adjacent frequency channels and geographic areas presented in ComReg document 15/73. The analysis undertaken in document 15/73 uses co-existence parameters that are based on those given in ECC Report 203 and are not specific to LTE.

Report 15/75 has been updated to make clear that it is not the intention to preclude other technologies.

ITU-R P.1410-07:

This reference was incorrect in the original report due to a typographical error, which has been corrected in the revision.

Appendix A: Plum Consulting's responses to the comments received from interested parties in response to ComReg consultation document 15/70 on 3.6 GHz spectrum award

A.1 Introduction

Concerns have been raised about whether the requirement for a specific TDD frame configuration (option 2 with 3:1 downlink/uplink ratio) would adversely affect operators deploying non-LTE technology. In this note we compare the frame structure of TD-LTE, WiMAX and Cambium's PMP450 proprietary system to assess the likely compatibility issues that might arise. The key finding is that the latest implementations of the PMP 450 system include a 5 msec frame option that is compatible with WiMAX and, by implication, also compatible with TD-LTE systems providing an appropriate frame configuration is deployed.

A.2 Comparison of Frame Structures

A.2.1 TD-LTE

TD-LTE has a standard frame length of 10 msec, which is subdivided into ten 1 msec sub-frames. There are three types of sub-frame, namely:

- Downlink
- Uplink
- Special (accommodates a guard period between uplink and downlink as well as pilot timeslots for the up and downlinks which can also be used for data transmission.

In configuration option 2, each 10 msec frame actually comprises two identical half-frames, so in practice the effective frame length is 5 msec, providing compatibility with WiMAX systems. The frame structure is illustrated below:

Figure A-1: Frame configuration for TD-LTE, option 2

◂1 msec▸

Sub-Frame	0	1	2	3	4	5	6	7	8	9
Frame type	Downlink	Special	Uplink	Downlink	Downlink	Downlink	Special	Uplink	Downlink	Downlink

◂— 10 msec —▸

In addition the Special sub-frame has ten possible configurations, depending on the required guard period (a longer guard period provides a larger cell size but lower throughput). The uplink and downlink pilot timeslots either side of the guard period (defined as DwPTS and UpPTS respectively) can be used for data transmission to supplement the other sub-frames.

Table A-1: Special sub-frame configuration options for TD-LTE

SSF configuration	Duration (µsec)		
	DwPTS	GP	UpPTS
0	215	714	71
1	643	286	71
2	714	215	71
3	786	143	71
4	857	72	71
5	215	642	143
6	643	214	143
7	714	143	143
8	786	71	143
9	429	428	143

A.2.2 WiMAX

WiMAX has a standard frame length of 5 msec and includes a total of 47 symbols that can be allocated to uplink or downlink transmission. The closest configuration to the TD-LTE option 2 in terms of downlink / uplink ratio comprises 35 downlink symbols and 12 uplink symbols. Analysis carried out by CEPT has shown that this configuration allows synchronisation with LTE systems using frame configuration option 2, so long as the Special sub-frame (SSF) configuration is set to 0,1, 5 or 6. A number of other Wi-MAX configuration options are also compatible, but only with LTE SSF configurations 0 and 5. A matrix identifying all the compatible sub-frame configurations for synchronised WiMAX and LTE networks is presented in Table 7 of ECC Report 216.

Note that the longer guard period for SSF options 0 and 5 results in a downlink throughput reduction of approximately 10%, due to the longer guard period, hence it is likely that the preferred options would be 1 or 6. This would constrain WiMAX deployments to the 35:12 downlink / uplink configuration to maintain synchronisation. Note also that systems deploying LTE SSF configurations 0, 1 or 5 can all be synchronised with systems deploying SSF configuration 6, since the uplink and downlink transmit periods are aligned except for the larger guard period between the two..

A.2.3 Cambium PMP 450

The Cambium PMP 450 product uses a proprietary wireless access technology with a dynamic TDD frame structure. Whilst earlier versions of the product had a 2.5 msec frame length, more recent versions (release 13.2 onwards) provide a 5 msec frame length option based on IEEE 802.16 d/e that is intended to provide "graceful migration of WiMAX Networks"[6]. By implication these systems should therefore be capable of synchronisation with TDD LTE systems deploying frame configuration option 2, in accordance with the matrix presented in Table 7 of ECC Report 216.

The PMP450 configuration procedure includes a frame calculator tool which calculates the length of the transmit and receive times within the frame, together with the number of downlink and uplink

[6] Source: "PMP 450 Update", presentation by Cambium Networks to workshop in Cork, September 2014 (http://azotel.com/00_Az_Docs/workshops/20140904-PMP450.pdf)

symbols for a given set of configuration parameters[7]. Cambium also provides an on-line colocation planning tool that calculates the key frame timing parameters based on user selected input values. Once the precise LTE frame configuration parameters are known[8], it should be possible to use this tool to select a frame configuration that will avoid any overlap between the transmit and receive frames in the LTE and PMP 450 networks.

Essentially, the configuration should be set so that the downlink transmit part of the PMP450 frame ends before the start of the uplink transmit part of the LTE frame and the transmit part of the LTE frame should end before the start of the receive part of the PMP 450 frame. The start and end times for the LTE downlink and uplink transmit parts can be determined from the special sub-frame timings defined in table 2 above and are as follows:

Table A-2: Transmit / Receive start / finish times for TD-LTE frame configuration option 2

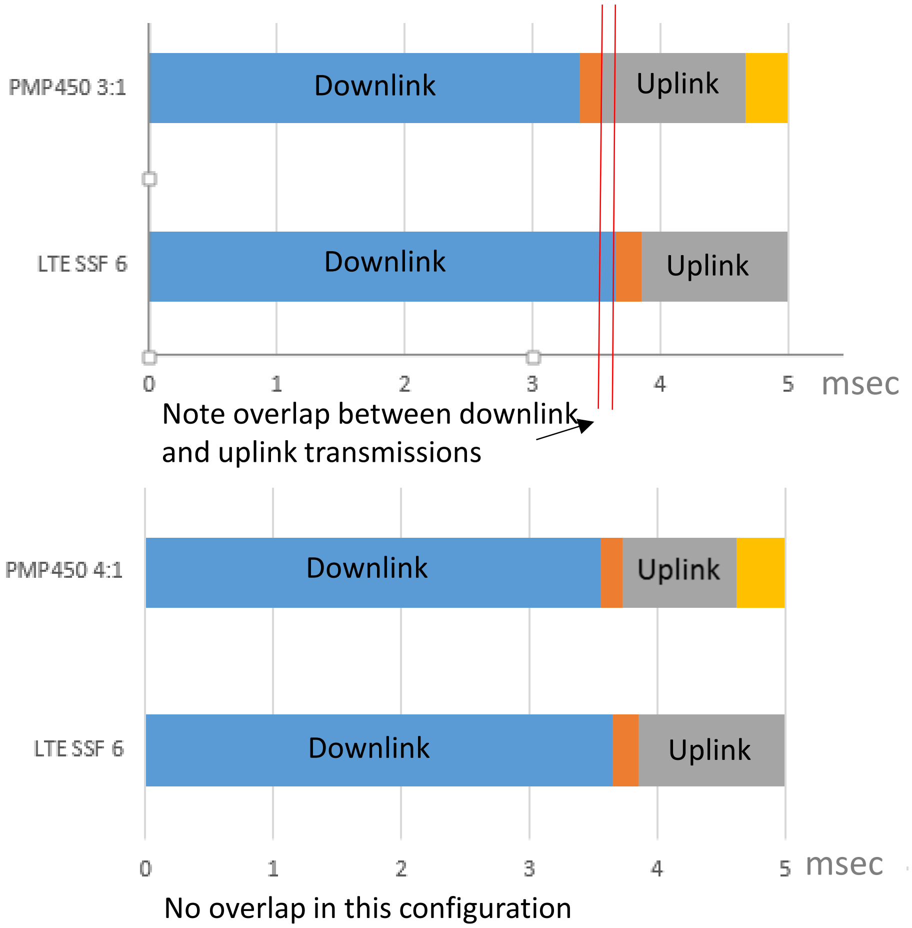
SSF configurati	Downlink start (mS)	Downlink finish (mS)	Uplink start (mS)	Uplink finish (mS)
0	0	3.215	3.929	5
1	0	3.643	3.929	5
2	0	3.714	3.929	5
3	0	3.786	3.929	5
4	0	3.857	3.929	5
5	0	3.215	3.857	5
6	0	3.643	3.857	5
7	0	3.714	3.857	5
8	0	3.786	3.857	5
9	0	3.429	3.857	5

Note that due to differences in the frame structure, compatibility may in some cases be better achieved by using a different downlink / uplink ratio in the PMP 450 system. For example, a typical PMP 450 configuration based on a 10 mile cell radius and 3:1 downlink / uplink ratio yields a downlink finish time of 3.37 msec and an uplink start time of 3.54 msec, according to Cambium's colocation tool. The latter is less than the downlink finish time for TD-LTE if SSF options 1 or 6 are deployed, meaning interference would arise. However if the downlink / uplink ratio is set to 4:1 the respective values become 3.56 msec and 3.73 msec, which means the PMP 450 uplink start time is after the end of the LTE downlink transmission and interference is avoided. This is illustrated in the figure below. Note that although differences in the specific frame structure can be accommodated (so long as the transmit and receive periods do not overlap), it is important the frames in both systems are aligned in terms of the start of the downlink transmission, to avoid the risk of this overlapping with the adjacent system's uplink.

[7] Source: "PMP 320 to PMP 450 Migration", Cambium Networks white paper, 2014

[8] Available at https://support.cambiumnetworks.com/files/pmp450/

Figure A-2: Frame alignment between adjacent PMP450 and LTE networks



A.3 Conclusion

The latest implementations of the Cambium PMP 450 wireless access product (Release 13.2 onwards) provide the option of a 5 msec frame length that is compatible with WiMAX (802.16e) and, by implication, also compatible with TD-LTE systems using frame configuration option 2. To ensure effective synchronisation between networks it will be necessary to know the precise frame configuration for the TD-LTE network, in particular the special sub-frame (SSF) option that is deployed and to set the transmit / receive timings in the PMP 450 system so that these do not conflict with the timings for the TD-LTE network. This can be done by setting appropriate parameters in the PMP 450 frame calculation tool. Note that this may result in a small reduction in the maximum throughput of the PMP 450 system (due to reduction in the uplink and/or downlink durations), but this would be offset by the benefit arising from deployment of the more permissive spectrum mask. Note also that the frames of the adjacent systems must be aligned in terms of the start of the downlink transmit period, to avoid the risk of transmit / receive overlap.

In the above discussions we have assumed that LTE special sub-frame (SSF) configuration 6 would be deployed because this has the shortest guard period and will therefore provide the highest throughput. However we note that this SSF option has more limited compatibility with non-LTE systems because the shorter guard period makes it more difficult to avoid overlap between the transmit and receive periods in adjacent networks. For example, according to table 7 in ECC Report 216, SSF 6 is compatible with only one WiMAX frame configuration, namely with a 35:12 downlink / uplink ratio, whereas options 0 and 5 also provide compatibility with four other WiMAX configurations (34:13, 33:14, 32:15 and 31:16 downlink / uplink ratios). However as downlink traffic is likely to be dominant we would expect networks deploying WiMAX to opt for the highest available downlink / uplink ratios anyway, which suggests there would be unlikely to be any overall benefit in restricting LTE networks to one of these lower throughput options. We would therefore recommend that SSF configuration 6 be assumed as the default option for TD-LTE networks in the 3.6 GHz band.

Such an approach would allow the deployment of alternative technologies such as WiMAX so long as the start of the downlink periods are aligned and there is no overlap between the uplink and downlink transmissions in the two adjacent networks (as illustrated in figure 2.1 above).

It should be noted that operation with other frame structures will be permitted subject to the restrictions set out elsewhere.