An Coimisiún um
Rialáil Cumarsáide
Commission for
Communications Regulation

DotEcon Report
Fixed Links Bands Review

Consultants Report

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Commission for Communications Regulation
1 Lárcheantar na nDugaí, Sráid na nGildeanna, BÁC 1, Éire, D01 E4X0.
One Dockland Central, Guild Street, Dublin 1, Ireland, D01 E4X0.
Teil | Tel +353 1 804 9600 Suíomh | Web www.comreg.ie

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Fixed links bands review - first report

Prepared for ComReg

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DotEcon Ltd
17 Welbeck Street
London W1G 9XJ
www.dotecon.com

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Executive Summary

DotEcon and Axon Consulting have been commissioned by ComReg to conduct a review of the fixed links bands and licensing approach in Ireland. This interim report sets our initial assessment of both current and expected future usage. Following this, there will be a review of the fee schedule for radio link licences, and a final report that incorporates the views of consultation responses. We stress that the findings and recommendations discussed are preliminary. We have yet to reach definitive conclusions and would welcome inputs from stakeholders.

Fixed link bands

Three licensing models for fixed links

Fixed links are currently operated in Ireland in multiple bands under three licensing models:

- Individually licensed links in the 1.3 GHz, 1.4 GHz, 2 GHz, 6 GHz, 7 GHz, 8 GHz, 11 GHz, 13 GHz, 15 GHz, 18 GHz, 23 GHz, 26 GHz, 28 GHz, 31 GHz, 38 GHz, 42 GHz and 80 GHz bands;
- Block licences in the 26 GHz band, with the three MNOs currently each assigned five 2×28 MHz spectrum blocks until 2028; and
- Licence-exempt usage in the 5 GHz, 17 GHz, 24 GHz and 60 GHz bands.

Bands allocated for individually licensed fixed links in Ireland, and their channel arrangements, are in line with international harmonisation and CEPT/ITU recommendations.

Fixed link bands are established by international coordination and support a wide range of different uses

The large number of fixed links bands is in line with approaches taken in other European countries (such as the UK, where over 20 bands are currently used for fixed links). The frequencies in use have grown organically through multiple rounds of international standards setting. As a result of many countries using the same bands, there is a global ecosystem for equipment for fixed link bands and manufacturers benefit from scale economies.

The broad frequency range spanned by the fixed link bands supports a variety of uses. Lower bands have better propagation characteristics and support longer links; higher frequencies have

more limited propagation, allowing shorter links only, but offer more much bandwidth.

No case for removing bands

Despite there being a large number of bands in use, and some only lightly used, removing bands would not be appropriate. Users need flexibility to make different trade-offs between link length and capacity requirement. We have found strong evidence that bandwidth requirements for fixed links are increasing and that this is unlikely to be reversed by increased fibre availability. In any case, it is unlikely that more valuable alternative uses exist for spectrum assigned internationally for fixed link use, and so these bands would be inefficiently left unused if not used for fixed links.

Bands harmonised for ECS

This said, two particular bands (1.4 GHz and 26 GHz) have been harmonised in Europe for electronic communications services (ECS). Whilst there is likely to opportunity for co-existence of fixed links with 5G services, over time more intensive 5G use is likely to require partial or full migration of fixed links to other bands.

Use cases

Exising use cases for fixed links are diverse

The main existing use cases for fixed links are:

- **narrowband telemetry and control** applications (where link length and reliability are the priorities);
- **broadcast distribution** (where fixed links are used when fibre cannot be used to reach isolated sites);
- **backhaul from mobile cell sites** (both isolated rural sites and also increasingly to interconnect dense networks of small cells in urban areas); and
- **fixed wireless access,** typically to isolated customers, but also in urban areas where fibre is not available or as a backup solution:
- **links within core networks**, where fibre is not available.

The main users of and current drivers of demand for individually licensed links in Ireland are the MNOs (who also hold national block licences in the 26 GHz band) and FWA operators. The majority of individually licensed links are for point-to-point (P-P) use; point-to-multiple (P-MP) use is now uncommon in the licensed bands.

Potential use cases

We have identified two new/potential use cases that may become more prominent in the future:

- **advanced fixed wireless access,** using new technologies (such as dynamic beamforming) that can support much higher capacities using mmWave bands, creating the potential to use P-MP and/or mesh systems to provide high-speed broadband in urban areas; and
- **specialist low latency links**, requiring low capacity links that cover long distances in relatively few hops e.g. for financial trading. (This use has only recently emerged in Ireland, but evidence from other jurisdictions, such as the UK, suggest this could become more prominent.)

Link length and bandwidth trade-off

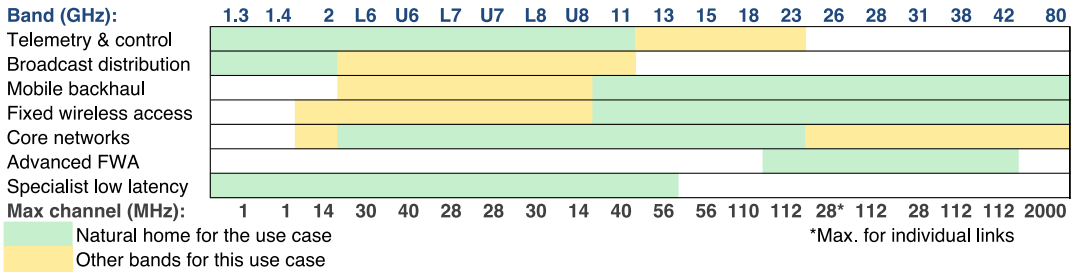
The spectrum requirements (in terms of bandwidth, link length and number of links) vary substantially across these use cases. There is a fundamental trade-off between link length and bandwidth, where:

- the lower frequencies can support longer and more reliable links, but typically have lower bandwidth due to more limited spectrum availability and smaller channels; and
- there is more capacity available in the higher frequencies, but link lengths are shorter and propagation more affected by atmospheric conditions.

Use cases vary in the extent to which link length or capacity is the priority. However, for any given use case, there is typically a range of frequency bands that can be used. Figure 1 sets out the bands that would be suitable for each use case.[1] It shows that a wide range of frequency bands is needed to support these different uses.

[1] This represents our understanding of the suitable bands based on what is feasible given the likely link requirements, not what is necessarily used in practice at present.

Figure 1: Bands suitable for each use case



Evidence suggests increasing bandwidth requirements

Analysis of ComReg licensing data and stakeholder interviews suggest that demand for spectrum for fixed links is being shaped by three main trends:

- increasing bandwidth requirements shifting demand to higher frequencies, in particular the 80 GHz band (where link lengths allow) and also the 18 GHz band (where larger channels are available than in the 11 GHz, 13 GHz and 15 GHz bands); and
- an increase in capacity requirements and use of dual polarisation where wider channels are not available;
- some replacement of microwave links by fibre (but not to the extent that their demand for fixed links would decrease significantly).

Interestingly, many of our interviewees considered that growing use of fibre is complementary with use of fixed links as (i) increased fibre prevalence is increasing consumers' expectations about required bandwidth for services and (ii) increased reach of fibre networks may create demand for fixed links to extend these networks to other inaccessible customers.

Switching between bands

Bands form a chain of substitutes

When users specify new links and first install new links, they typically have flexibility with regard to which band to use, as a number of bands may provide acceptable bandwidth and link length. This means that the various bands form a chain of substitutes. Hypothetically, spectrum in one band can – over the long term – be freed up by moving existing users into one of their alternative acceptable bands. Therefore, although low and high frequency bands have very different characteristics and may not be direct substitutes, intermediate bands each in turn provide alternatives for bands above and below them. This means that we cannot readily split bands into distinct, non-overlapping groups according to how they are used.

Short-run substitution possibilities may be limited

Despite this high degree of flexibility in the long run, in the short run, there may be considerable barriers to existing users moving into alternative bands. Equipment is generally only tunable across a small range of frequencies. Moving to a different band, or even a different sub-band, may be costly as hardware needs to be swapped. A users changing of the bands it uses is therefore likely to be linked to equipment being replaced as part of its natural life-cycle.

Price signals and choice of congested bands

It may be possible to use fees to steer new users away from congested bands, but this unlikely to create any significant incentive for existing users to switch band. Furthermore, because new users typically have a fair degree of choice which bands to use, they may naturally tend to steer away from congested bands without needing a large price differential between bands. New users will likely tend to choose bands to avoid making unsuccessful applications for fixed link licences that conflict with existing users and, in some cases, to provide better options for future capacity expansion without needing to switch band later.

Congestion and efficient allocation

Current congestion in the Dublin area

Whilst there is plenty of spectrum for fixed links overall, certain bands have become congested, but in certain locations only. There is currently congestion in Dublin in the 13 GHz, 15 GHz, 18 GHz, and 23 GHz bands. As a result ComReg no longer issues new licences in the 13 GHz and 15 GHz bands in the congested area. A congestion charge is imposed on links in the 18 GHz and 23 GHz bands in the congestion area. We do not currently see congestion problems elsewhere, but this does not mean they will not arise in the future if there increasing demand for bandwidth clustered at particular locations.

Importance of information

In practice, achieving efficient use of the available bands depends primarily on good information being available to users about emerging demand, allowing assessment of where congestion is likely to arise. Such information would allow operators to make informed and better network planning decisions, where possible avoiding clashes by moving towards bands less in demand. This may help to avoid congestion.

Where congestion does emerge, ComReg's approach of applying a congestion charge to reflect the incremental long-run opportunity cost of the spectrum is appropriate. However, because users are typically able to switch to close alternative

bands with little loss, this long-run opportunity cost is typically limited. Large price differentials between bands should not be necessary to induce switching away from congested bands by new users.

Therefore, our preliminary view is that the successful management of congestion in certain bands is primarily a question of the information available to users when applying for fixed link licences and ensuring that they understand how demand is evolving in different bands to best choose between alternative bands. There may be some benefit in formalising a measure of congestion that is regularly reported to potential users and which can be used to determine when a congestion charge applies (or is likely to apply in future) in a band, in a particular area.

Congestion management and spreading across bands

As explained above, we do not need to be overly concerned about this approach to congestion management leading to users spreading out across many fixed link bands. With the exceptions of the two bands identified for ECS, there is no immediate alternative use for fixed link bands and their frequencies are well-established through international harmonisation. An approach to congestion management that encourages users to spread to substitute bands where possible is beneficial as it keeps options open for new fixed link licensees. This agility is valuable to users, as a key attraction of fixed links is that they can be rapidly deployed with limited physical infrastructure.

Impact of fibre on demand for fixed links

More fibre will not eliminate the need for fixed links

Fibre rollout is likely to have a significant impact on demand for fixed links as many microwave links are likely to be replaced as the reach of the fibre network expands into areas not previously served. However, the clear message received from our engagement with stakeholders is that (at least for the foreseeable future) there will continue to be demand for microwave links as:

- some locations cannot be economically reached with fibre even as the fibre network expands;
- reaching remote sites with fixed links may become economic as the closest fibre becomes closer, even if it does not reach to the site itself; and
- fixed links may be used as backup connections, either to provide resilience through a different route or

because a second, differently routed fibre connection would be too costly.

Possible increased demand for fixed links

Many stakeholders thought there may be a complementary relationship between fibre and fixed link demand. In particular, as fibre network coverage expands:

- the increased reach of fibre may stimulate business activity in rural areas, which in turn may create increased demand for microwave links as backup or for reaching sites that are just out of reach of fibre; and
- demand for backup microwave connections in general may increase as businesses seek additional reliability in their connectivity and expectations about bandwidth increase due to the increased availability of fibre services.

Shift to higher frequencies

With increased rollout of fibre, microwave links will tend to become shorter (as fibre nodes will be closer on average to end points) but higher capacity, leading to a corresponding shift into higher frequencies. ComReg's licensing data already suggests that there is a general shift in demand into the higher frequency bands (in particular into the 18 GHz and 80 GHz bands).

Channel widths

Some stakeholders said they want wider channels than are currently available in certain fixed links bands (in particular the 11 GHz, 13 GHz and 15 GHz bands).

Benefits of wider channels

In general we do not see any downside to making wider channels available, where feasible and in line with international recommendations. However, ComReg currently (and appropriately) adheres to CEPT/ITU recommendations on channel arragements and offers the maximum channel widths allowed by the recommendations in each band. ComReg's ability to make wider channels available is, therefore, constrained by these recommendations.

However, the most recent ITU channel spacing recommendation for the 15 GHz band has guidelines to implement 112 MHz channel spacing. This has not yet been adopted by ComReg, but we anticipate that it will be introduced in Ireland in the near future. In addition, ComReg might have scope to make wider channels available in other bands, because:

- the ECC is considering doubling the maximum recommended channel width in a number of fixed links bands (although not in the 13 GHz band); and
- the CEPT/ITU recommendations also allow for NRAs to combine channels to allocate larger channels than are included under the recommended approach, but in most cases ComReg does not currently make use of this option.

Fragmentation

Where bands are offered in channels of different sizes, as might happen naturally if channel sizes are increased, there is some potential for fragmentation (i.e. gaps between smaller channels preclude allocation of large channels). This has not been a significant issue to date, but the general trend towards larger bandwidths could lead to fragmentation being more prevalent in the future in areas where a significant number of smaller channels remain in use. This may be problematic if there is future congestion, as opportunities to accommodate potential licensees in a band may be lost. However, there may be limited scope for ComReg to address such fragmentation under the current individual link licensing regime. We welcome any views from stakeholders on this issue.

Spectral efficient technologies

There are a number of technology developments that can help to improve the efficiency of spectrum usage (i.e. achieve more capacity per MHz).

- XPIC;
- Carrier aggregation;
- Frequency re-use techniques;
- MIMO;
- Automatic Transmit Power Control (ATPC); and
- Adaptive Coding and Modulation (ACM).

Some of these have been available for some time. XPIC, for example, has been used (and encouraged by ComReg) in Ireland for many years. Others are only recently commercially available or are still in development.

Incentives to take-up of advanced technologies may be weak

Our understanding from our interviews is that operators typically prefer access to more bandwidth for achieving greater capacity, as more advanced equipment is more expensive. Therefore, there is little incentive for users to minimise spectrum usage. This is not in itself problematic unless spectrum for fixed links (in some appropriate range of bands) becomes scarce.

Nevertheless, these technologies are likely to become more important in the future for supporting increasingly large capacity requirements and efficient spectrum utilisation. Therefore, it is again important that potential future users having good information about potential emerging pinch points, in terms of locations and bands where scarcity may occur. Scarcity charging may have some role in encouraging licensees to economise on spectrum usage through the use of more efficient equipment.

Block licensing

Advantages of block licensing at higher frequencies

For some frequency bands, there may be advantages to block licensing. This applies particularly to the higher frequencies, where links are likely to be densely deployed and radio modelling of interference at a sufficiently fine geographical level may not be feasible. Block licences allow for greater frequency reuse, better frequency management, guaranteed availability of spectrum for new links, and lower cost of equipement spares. However, the benefits need to be weighed against the risk of sterilising use of the spectrum for other users that could coexist.

Regional block licensing

Regional block licences, and in particular "micro" licences in urban centres might be appropriate for high frequency bands where usage is likely to be fairly localised. In this case it may be sufficient to have block licences in the cities, but individual link licences elsewhere.

Block licences are not suitable for all

We recognise that block licences are not likely to be suitable for all users, for example in cases where the number of links operated is low or uncertain (and volatile). Assigning a band manager or allowing for shared licences may be helpful in this case.

Block licences may be more appropriate in new bands

Although block licences may be beneficial, it is unlikely to be desirable to introduce block licensing in bands where individual link licences are already issued. This is due to the likely cost and complexity of clearing/migrating existing users of individual links who may need to adapt their equipment/networks to use alternative frequencies. It is more realistic, therefore, to make new block licences available in greenfield bands that could be opened for fixed links. We welcome views from stakeholders on this issue.

Block licences in the 80 GHz band

There is an open question over whether block licensing is still possible in the 80 GHz band, which may be particularly useful in urban areas. Current usage of the band (especially in Dublin)

suggest that this is unlikely to be viable, but would welcome the views of stakeholders.

Licence-exempt spectrum

Operators are free to use spectrum in a number of licence-exempt bands, subject to maximum power restrictions, without notifying ComReg (except in the 5.725 – 5.875 GHz band where registration is required as the power limits are less strict than the other parts of the 5 GHz band). There are no fees for using licence-exempt spectrum and operators may access it immediately. However, no interference protection is provided and users must coordinate with one another to avoid interference issues.

Attractions of licence exempt spectrum

Licence-exempt spectrum is attractive to operators that need to be able to deploy links quickly and/or are not reliant on the interference protection provided by the licencesed bands. FWA services in the 5 GHz band are currently the most common use case in the licence exempt bands (based on RFI responses).

In 2012, the 17 GHz band was removed from ERC/REC 70-03 for short range devices (SRDs), following identification of the 15.4 – 17.3 GHz band by the ITU for radar applications. However, we understand that there is no restriction on the band being used for fixed links, and suggest that it remains available unless there is good reason not to.

The 60 GHz band is not heavily used in Ireland at present, but we anticipate that it will become more important in the future, for example for localised, high capacity dense-cell applications. We note that ComReg has recently expanded the spectrum available in the band for licence-exempt fixed links (to now include 66 – 71 GHz). This should help to maximise usage of the band, but also to help free up (or keep free) spectrum in the licensed bands.

The 60 GHz band is susceptible to signal degradation due to attenuation by atmospheric oxygen and, as such, is better than other bands at similar frequencies at coping without formal interference protection. Therefore it is appropriate for the band to be available on a licence-exempt basis even if it becomes more heavily used.

ECS/MFCN in the 1.3/1.4 GHz, 26 GHz and 42 GHz bands

The 1.3 GHz, 1.4 GHz, 26 GHz and 42 GHz bands have been identified at international level as important bands for 5G.

1.4 GHz

The 1427 – 1517 MHz has been harmonised at a European level for 5G, with Member States required to make the band available for ECS by 2023 (provided there is demand).[2] These frequencies encompass the full upper parts of the 1.3 GHz and 1.4 GHz bands currently used for fixed links. Although, the Decision allows for the frequencies to be used for other use cases beyond 2023 if there is no demand to use it for wireless broadband, we anticipate that it will be necessary for fixed links to be migrated out of the band at some point in the future (potentially within the next three years). ComReg has already considered this as part of its Multi-Band Spectrum Award (MBSA2) and we would suggest that ComReg revisit this matter following the completion of the MBSA2. We also note that sufficient notice would need to be given to existing users regarding the need to migrate fixed links elsewhere.

26 GHz

The 26 GHz band has been identified as a pioneer mmWave band for 5G and has been harmonised by CEPT for MFCN. Member States are required to make at least 1 GHz available in the band for 5G by the end of 2020, subject to demand, with the view of making the whole band available to MFCN in the long run. Responses to the MBSA2 process indicate a current lack of demand for spectrum in the 26 GHz band for ECS[3] and that NRAs are currently provided with a range of options for introducing 5G into the band, which includes the potential for coexistence between 5G and other use cases (such as fixed links). However, the likely timing of signifcant 5G use in the band is currently unclear.

We understand that ComReg is conducting a separate project in relation to the future use of the 26 GHz bands, where this issue will be addressed further. Without prejudice to the findings and recommendations that emerge from this separate study, we are currently of the view that there is no immediate need to make any changes in relation to current usage of the band for fixed links, and in particular believe that the current block licences

[2] European commission implementing decision (EU) 2018/661

[3] See paragraph 3.115 of Document 19/59R and section 3.2.3 of Document 19/124

can continue until the planned expiry in 2028. It would seem prudent that ComReg provides current users with clear and sufficient notice of its plans as they become apparent.

42 GHz

The 40.5 – 43.5 GHz (42 GHz) band has been identified as a 5G priority band, although developments are less advanced than for the other two bands. A CEPT work item is currently underway to develop harmonised technical conditions for next-generation (5G) terrestrial wireless systems, with a final report due in July 2021 following a public consultation process. Although the 42 GHz band is not heavily used for fixed links at present, we do not see any need to adjust the approach to fixed links in the band at least until more information is available regarding the CEPT harmonisation plans. Again, it is important that users are given sufficient notice of any planned changes to the system as and when they arise.

Making more spectrum available

Candidate bands

In its RSMSS[4] ComReg set out its intention to investigate the possibility of opening up frequencies in the D-band[5] for fixed links. During the stakeholder interviews, it was also suggested that the W-band[6] and the 32 GHz band could be made available. These bands are likely to be relevant to high capacity links and advanced FWA services. Overall there does not seem to be any urgency for making these bands available, but ComReg should consider setting out a high level roadmap for when they might be released.

The D Band and W band and block licensing

The D band and the W band both offer large amounts of contiguous spectrum. In particular, there is over 30 GHz available in the D band and over 15 GHz of spectrum available W-band. While both may be suitable for high capacity links, the W-band is seen as an extension to the 80 GHz band, whereas the D-band has particular potential for use with advanced technology such as flexible FDD (fFDD).

Although the ECC provides example channel arrangements for the bands, they are not yet harmonised, technical specifications (e.g. ETSI standards) are not yet available (though expected by the end of this year) and equipment for the bands is still being developed. Furthermore, feedback from our interviews

[4] ComReg 18/118, Section 5.2.4

[5] 130 – 134 GHz, 141 – 148.5 GHz, 151.5 – 164 GHz and 167 – 174 GHz

[6] 92 – 94 GHz, 94.1 – 100 GHz, 102 – 109.5 GHz and 111.8 – 114.25 GHz

suggested that while these bands might be useful in the future, there is no immediate demand for them at present

We do not recommend making these bands available until there is a clear need for the spectrum and suitable equipment is available. Nevertheless, ComReg should consider setting out a plan for making the bands available at some point. If/when they are released for fixed links, we envisage them being good candidates for block licences (and in particular micro block licences) given the likely deployment in dense clusters and the implications for link by link interference analysis.

The 32 GHz band

The suggestion to open the 32 GHz band was made on the basis that it could provide a good alternative to the 26 GHz band if block licences were to be ceased in the band as a consequence of 5G demands. In this case the band would not need to be made available until much closer to 2028 when the 26 GHz block licences are due to expire.

However, there may well be other use cases for the band that could use the spectrum much earlier. For example, we are aware of the development of advanced FWA services using technologies that are suited to the mmWave bands[7]. In this case there would be little justification for withholding the band and not making it available sooner give potential pro-competitive benefits from new services.

Coexistence with satellite services

Limited current problems

ComReg has highlighted that some of the fixed links bands are currently also used for satellite services connecting to earth stations. Our initial view is that coexistence of satellite and fixed links is unlikely to be a major concern, as fixed satellite earth stations and fixed links currently co-exist on a co-primary basis in the certain frequency bands in Ireland and across Europe. Coexistence measures are already in place, as specified in ECC Decisions and Reports, and interference should be easily manageable and not widespread. ComReg's licencing team would work directly with earth stations to find a suitable location and avoid potential interference concerns.

New framework for satellite licensing

We note that in it's Annual Action plan for 2020/2021, ComReg intends to consult on a new licensing framework for satellite earth stations and terminals. We understand that as part of that work item, ComReg would consider the coexistence and

[7] See, for example, https://starry.com/technology

coordination of satellite earth stations with fixed links. Notwithstanding, we invite respondents to provide their views on the use of the bands, identified in this report, on a co-primary basis between fixed links and satellites.

1 Introduction

The Commission for Communications Regulation (ComReg) has engaged DotEcon Ltd (DotEcon) and Axon Consulting (Axon) to assist with its review of the fixed links bands and licensing framework in Ireland.

1.1 Background

Current fixed links bands and licensing regime

Fixed links licences in Ireland are currently assigned in 20 different frequency bands (the fixed links bands), ranging from 1.3 GHz to 80 GHz (see Annex A for a detailed breakdown of the bands). There are three ways in these are currently assigned by ComReg:

- **Individual link licences**[8]: these authorise the licensee to operate a fixed link between specified geographic locations using particular frequencies and power limits. Individual link licences run for one year but can be renewed annually. Licensees pay annual fees (set out in ComReg's Radio Links Guidelines[9]), based on the frequency band, bandwidth assigned and whether or not the link would be within a congested area (Dublin) or on a high usage path. Individual link licences are currently available in the 1.3 GHz, 1.4 GHz, 2 GHz, 6 GHz, 7 GHz, 8 GHz, 11 GHz, 13 GHz, 15 GHz, 18 GHz, 23 GHz, 26 GHz, 28 GHz, 31 GHz, 38 GHz, 42 GHz and 80 GHz bands.
- **National point-to-point block licences**[10]: licensees are assigned a duplex block of spectrum that can be used for fixed links nationally. Currently, block licences have only been assigned in the 26 GHz band and these were assigned via an auction process in

[8] Wireless Telegraphy (Radio Link Licence) Regulations, 2009 (S.I. 370 of 2009)

[9] https://www.comreg.ie/media/dlm_uploads/2017/06/ComReg-0989R2.pdf

[10] Wireless Telegraphy (National Point-to-Point) Regulations 2018 (S.I. 158 of 2018)

2018.[11] The 26 GHz national block licences will run for a total of 10 years (to 2028), and fees were determined as part of the award process (split into an upfront fee and ongoing annual spectrum usage fees).

- Fixed links may also be operated on a **licence exempt** basis in designated bands, namely the 5 GHz, 17 GHz, 24 GHz and 60 GHz bands.

The majority of fixed links in Ireland are individually licensed point-to-point (P-P) links, and the most common use case is backhaul for mobile networks (although there are a number of other uses). Some licences allow for point-to-multipoint links (P-MP), although these licences are much less common than P-P.

A wide range of frequencies is necessary to support a variety of link lengths/capacities

The wide range of frequencies available for fixed links is necessary to support the different link length/bandwidth combinations required by the various applications and services that rely on fixed links. Lower frequency bands allow for long link lengths (hops) but are limited in the bandwidth available, whereas higher frequencies are suitable only for shorter hops (as propagation is shorter and links are more affected by atmospheric conditions) but offer much greater capacity. The most suitable band (or range of bands) for any given link is therefore determined by the specific distance and capacity required for the intended application, and these can vary significantly across different use cases. For example, broadcasting services typically have fairly modest capacity requirements but may need to transmit over long distances (over 50 km) to remote hilltop sites, making lower frequency bands (e.g. 1.3 – 2 GHz) the most appropriate. On the other hand, a fixed wireless operator looking to provide a business customer with 'fibre-like' wireless broadband may only need to run a link over a short distance to connect to its core network, but would be reliant on the greater bandwidth and higher data rates offered by the higher frequencies to meet the speeds demanded by the customer. In this case, the required link length varies from customer to customer, and as a result some use cases are found in a larger number of bands.

The seemingly large number of bands used for fixed links in Ireland is not unusual. In the UK, for example, Ofcom allocates

[11] The three MNOs (Vodafone, Three and Meteor) were each assigned five 2x28 MHz blocks. Further details can be found at https://www.comreg.ie/industry/radio-spectrum/spectrum-awards/26-ghz-spectrum-award/

fixed links licences in over 20 bands[12], most of which are also used for fixed links in Ireland, and this is fairly typical amongst other European jurisdictions.[13] Indeed, the specific frequency bands allocated for fixed links in Ireland are determined by ComReg in accordance with Electronic Communications Committee (ECC), European Conference of Postal and Telecommunications Administrations (CEPT) and International Telecommunication Union (ITU) recommendations and international harmonisation measures. Following established international norms is essential to ensure operators have access to an established, supported and developing device ecosystem. Manufacturers of equipment for fixed links operate at global scale.

5G in the fixed links bands

Two of the bands currently used for fixed links have been harmonised in Europe for electronic communications services (ECS), namely the 1.4 GHz and the 26 GHz bands. Although there is some degree of flexibility over the timing and manner in which CEPT administrations may introduce 5G into these bands, in the short-term continued operation of fixed links may be possible if such fixed links can coexist with mobile services through managed shared spectrum use. In the longer term, more intensive 5G use makes it is likely that fixed links users will at some point need to be migrated (partially or in full) out of these bands. Other fixed links bands have been considered for, but not assigned to, ECS at this point; in particular, we note that the ECC is currently working on harmonisation of the 42 GHz band.

Congestion

Congestion occurs when there are many links in a band along similar paths, such that it is difficult to fit in a new link in that band. ComReg has already defined a 'congested area' around South Dublin and Dublin City Centre, in which it has taken measures in bands that have already experienced congestion, namely ceasing to accept applications in the 13 GHz and 15 GHz bands in 2014[14], and applying a congestion charge in the 18 GHz and 23 GHz bands since 2009. In discussing congestion, we use 'urban' to refer to links in the five cities (i.e. Dublin,

[12] Similar to the case in Ireland, fixed links in the UK are allocated via individual link licences, blocks licences, light licensing and on a licence exempt basis.

[13] A detailed breakdown of the bands allocated by European administrations for fixed links (as of 2018) can be found in ECO Report 04 (https://docdb.cept.org/download/a0e4697a-e0ab/EcoRep04.pdf).

[14] ComReg 14/32

Waterford, Limerick, Cork and Galway), and 'rural' to refer to links elsewhere.

As we discuss subsequently, there are usually opportunities for new fixed links to move to alternative bands, even if a user's most preferred band is congested. Therefore, even when individual bands are congested, users are rarely faced with overall resource scarcity, in the sense of a potential fixed link user being denied opportunity to set up a fixed link appropriate to its use case due to contention from other users.

1.2 Scope of this interim report

ComReg's plans to review the fixed links framework

As part of its Radio Spectrum Management Strategy Statement for 2019 – 2021[15], ComReg has proposed to conduct a review of the current fixed links licensing regime and the technical guidelines for fixed radio links. This includes potentially opening up four 'candidate bands' (in the 130 – 174 GHz range), and will include a review of the pricing methodologies and resulting fee schedule at a subsequent stage, following any potential amendments to the bands available for fixed links.

ComReg's statutory objectives

The fixed links framework, and any changes made following this review, will need to support ComReg in meeting its statutory objectives in the context of electronic communications, in particular to:

- promote competition;
- contribute to the development of the internal market;
- promote the interests of users within the Community;
- ensure the efficient management and use of the radio frequency spectrum in Ireland;
- under Regulation 19 of the Authorisation Regulations, impose fees for rights of use, which reflect the need to ensure the optimal use of the radio frequency spectrum; and
- unless otherwise provided for in Regulation 17 of the Framework Regulations, take the utmost account of the desirability of technological neutrality in complying with the requirements of the Specific Regulations, in particular those designed to ensure effective competition.

[15] https://www.comreg.ie/publication/radio-spectrum-management-strategy-statement-2019-to-2021/

Role of DotEcon and Axon

DotEcon and Axon are assisting ComReg with this wide-ranging review. In this initial report we summarise our preliminary findings, with a view to encouraging responses from stakeholders. This sets out our understanding of the current situation regarding fixed links in Ireland and our expectations about its future development.

These initial views are based on a combination of:

- desk research;
- analysis of data on past and current fixed links licences allocated in Ireland;
- the relevant CEPT/ITU recommendations and decisions;
- information gathered during a number of interviews held with fixed links stakeholders (current users and equipment manufacturers);
- responses received to a voluntary request for information (RFI) sent out to all current fixed link licensees; and
- responses received to an RFI sent by ComReg to members of BEREC.

We emphasise that no firm conclusions have yet been reached and we will consider relevant inputs from stakeholders in the next phase of our work. This will lead eventually to a final report that will make recommendations to ComReg on the licensing regime.

1.3 Structure of the report

Structure of the report

The remainder of the report is structured as follows:

- Section 2 sets out our understanding of the key current use cases for fixed links and recent trends observed in the licensing data;
- Section 3 identifies emerging trends that should inform the design of the licensing framework going forward;
- Section 4 consolidates our views on the key fixed links use cases and sets out use cases other than fixed links that the fixed links bands may be (or are) used for;
- Section 5 discusses the key issues relating to each of the fixed links bands and provides some preliminary

views/recommendations for ComReg and stakeholders to consider;
- Section 6 sets out the broad licensing options available to ComReg and provides some preliminary views on these and how they might be applied; and
- Section 7 sets out our interim conclusions.

There are also a number of annexes:

- Annex A summarises the current licensing regime for fixed links;
- Annex B gives details of our stakeholder interviews and information from ComReg's request for inputs;
- Annex C provides an analysis of ComReg's fixed link licensing data to show usage and trends in the various bands.

2 Current trends in use of fixed links

In this section we outline our understanding of the key existing use cases for fixed links in Ireland, and consider relavant trends in usage patterns in licence data from the last ten years.

2.1 Existing use cases

In summary, we believe that the most important current use cases for fixed links are:

- **narrowband telemetry and control** applications (where link length and reliability are the priorities);
- **broadcast distribution** (where fixed links are used when fibre cannot be used to reach isolated transmitter sites);
- **backhaul from mobile cell sites** (both isolated rural sites and also increasingly to interconnect dense networks of small cells in urban areas); and
- **fixed wireless access,** typically to isolated customers, but also in urban areas where fibre is not available or as a backup solution:
    1. via point to multipoint (P-MP) links for broadband services primarily aimed at domestic customers in rural areas; or
    2. using point to point (P-P) links for delivery of services to customers with high bandwidth requirements (such as business customers).
- **links within core networks**, where fibre is not available.

2.1.1 Telemetry and control

Use of fixed links for telemetry and control is typically narrowband and tends to prioritise link length and reliability. These applications have modest bandwidth requirements that are unlikely to increase in future. For these reasons, they typically use the lower frequency bands (i.e. up to around 8 GHz). Typical link lengths tend to be in the 10–80 km range

and the lower frequencies are needed to cover the required distances.

Utilities are key operators of fixed links for telemetry and control purposes. Their needs for particular bands will be determined by the distance between their closest network nodes and the sites being monitored, with the latter distributed throughout the country. In many cases, major infrastructure may have wired (typically fibre links) and utilities run their own dedicated fixed networks independent of public networks for reliability and security. However, it is impractical to extend fixed networks to large numbers of minor remote sites, so fixed links are essential connecting these.

Although capacity requirements are likely to be relatively low, these services (e.g. support to the electricity network) are critical, meaning that reliability is of high importance. Where fixed links are used in the network they will need to provide a very high degree of reliability. Fixed links may also be used alongside fibre connections within utilities' private networks to provide redundancy.

2.1.2 Broadcast distribution

Fixed links are commonly used for broadcast distribution to remote transmitters, particularly used where fibre cannot be used to reach isolated high sites, often in the 1.3 GHz and 1.4 GHz bands. Link lengths tend to be in 10-65 km range.

Broadcasting links are widely distributed throughout the country, and the appropriate bands will be determined based on the required link length requirements, which in turn are driven by the need to locate broadcast transmitters at high sites. By their nature, these sites are often somewhat remote and unpopulated.

We understand that capacity requirements are fairly modest (set by the data rates required for broadcast channels or multiplexes) and, expected to remain fairly stable for most broadcasters. Therefore, the predominant requirement is for long links, rather than high bandwidth.

2.1.3 Mobile backhaul

The mobile network operators (MNOs), eir, Three, and Vodafone, (jointly) currently hold the greatest number of

individually licensed fixed links (alongside their block licences). These are used primarily for backhauling traffic from mobile cells in their radio access network (RAN) to their core network, in particular to:

- connect sites in isolated rural areas back to the rest of the network, which may require relatively longer links; and
- interconnect dense networks of small cells in urban areas, which typically only requires short links, but at high bandwidth.

These two scenarios create rather different requirements depending on likely link lengths. Bands above 42 GHz are unsuitable for rural links, however link length constraints may apply even with one end of the link in a city, where key high sites with good visibility of city centres are sufficiently far away, as is the case in Dublin. For short, high bandwidth links, MNOs already use 80 GHz spectrum within cities where possible.

We note that there is a reasonable likelihood that parties other than the traditional MNOs could become involved with deployment of small cells. Indeed, Airspan acquired spectrum in the 2017 auction of 3.6 GHz, apparently with a view to furthering such a business model. Therefore, potential demand for fixed links to support small cell backhaul is not limited to only the three current MNOs.

If dense, small cell mobile networks in urban areas become common, both as a result of 5G and because of the underlying trend of increasing demand for bandwidth from end customers, an increasing proportion of MNOs' links may be in the higher frequency bands. Where there are a large number of cells within a small area (for example attached to street furniture or contained in shop hoardings), it may be either cost prohibitive or simply infeasible to run fibre to each site. Therefore, there is likely to be significant and growing demand for short wireless links to connect small cells. Although we have observed the 80 GHz band becoming increasingly important, we are aware that other technologies are available to MNOs, such as intregrated access backhaul (IAB) where the same mmWave frequencies can be used for access and backhaul[16], that would not require such high frequencies.

[16] https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/introducing-integrated-access-and-backhaul

At the high frequencies needed to deploy short, high-capacity links, the interference environment will tend to be very localised. For example, within a city if links run along a street, buildings may contain signals and allow that frequency to be re-used for other links nearby. Therefore, although links may be densely deployed, there may many opportunities for coexistence. The 60 GHz, 80 GHz and the candidate bands may all be useful for dense deployment of links, dependent on interference protection requirements and when the spectrum and relevant equipment are available (particularly for the candidate bands).

In addition to cell backhaul requirements, it is possible that there could be future demand for mobile "fronthaul" (i.e. connecting antenna sites to a Cloud-RAN, as opposed to connecting the RAN to the core network) if RAN structures change substantially in the 5G era. At least in principle, demand for fixed links for these purposes should have similar characteristics to backhauling small, high-bandwidth cell sites.

2.1.4 Fixed Wireless Access

Fixed Wireless Access (FWA) is already an established service in Ireland and is one of the primary use cases for fixed links, both for connecting end users and for backhaul into the core network. FWA services span a range of business models, including:

- services aimed at customers requiring higher bandwidth connections, typically provided as dedicated point-to-point links; and
- broadband services using point to multipoint networks, primarily aimed at domestic customers with low bandwidth requirements in rural areas.

Dedicated point to point links

A key role for FWA is to provide high bandwidth connectivity to isolated customers (primarily businesses), in rural areas where fibre deployment is not economically viable, although some

operators also provide high capacity services in the cities.[17] Speed requirements for business connections have been growing, with new connections increasingly targetting 1 Gb/s.

We can expect the roll-out of fibre to rural areas, both commercially and on the back of the National Broadband Plan, to increasingly provide for residential broadband connections. At the same time, there is significant and growing demand for bandwidth at isolated locations for business customers, where wireless services may have cost and flexibility advantages relative to installing new fibre.

Links for these services are typically installed on a customer-by-customer basis, such that demand from operators for new links (or conversely the cancelling of licences for existing links) is driven predominantly by customer demand. Each time a new customer is gained or, an existing customer wants an upgrade, the operator will need to find an available link in a band that that covers a sufficient distance to reach that customer from a network node and also gives sufficient bandwidth to meet the speed requirements. Links for FWA services are therefore typically spread across a number of bands depending on their specific speed and length requirements, which vary from case to case. As of 2020:

- over half (>2,000) of their links are in the 11 – 23 GHz bands;
- nearly a quarter (>1,000) links are in the 80 GHz band;
- over 500 FWA links across the 28 GHz and 38 GHz bands; and
- over 350 links held by FWA operators are in the 6 – 8 GHz bands.

Therefore, while the higher bands are increasingly important for FWA services, we do not expect the use case to be concentrated in a small number of bands at any.

Point to multipoint broadband access

Existing P-MP links in Ireland are typically used for broadband access, mostly to connect a number of premises with low

[17] We note that in the future there may be some scope for 5G FWA to provide an alternative to fixed links in some cases, in particular where there is a sufficient density of consumers to make the infrastructure investment worthwhile. However, our understanding is that this is likely to be some way off, and in any case there will be limitations that mean it 5G FWA is unlikely to provide an alternative to fixed links for all applications.

bandwidth requirements in rural areas (e.g. homes, businesses with small backup requirements, schools, or the user's own offices). P-MP links in operation in Ireland include:

- 30 links in the licensed fixed links bands (as of 2020, compared to over 12,500 P-P links), down from 94 in 2018 largely as a result of ESB cancelling a number of its P-MP licences[18];
- Eir's RurTel service in the 2.3 GHz band, which makes up most of the licensed P-MP links, serves very few customers in remote areas of Donegal (following the discontinuation of the service in Galway and Kerry) as a means of fulfilling Eir's Universal Service Obligation (USO). The remainder of these links may be cleared from the band as part of MBSA2[19]; and, more commonly,
- P-MP links operated by FWA operators using the licence exempt bands (primarily 5 GHz) to provide low bandwidth broadband to small groups of customers (which typically generate a relatively small amount of revenue, and hence the licence-exempt spectrum is attractive for these applications).

During the stakeholder interviews there was a mix of opinions on the future of P-MP use. Although P-MP broadband provision in rural areas may continue in cases where there are few alternatives available (e.g. due to a lack of fibre in the area), a number of stakeholders suggested that it is likely to play a limited role, in particular with current systems offering limited capacity in a world with ever-increasing bandwidth requirements. However, the emergence of new technologies suggests that P-MP links in higher frequency bands are likely to play a key role in the future (discussed further in Section 3.5).

2.1.5 Links within core networks

Point-to-point links are used within the core networks of a range of different users (including the MNOs and FWA operators also using P-P links in their access networks or to backhaul traffic from their access to their core networks as described above). Typically, fixed links connect sites within the

[18] ComReg, 2020, 'Fixed Radio Links Annual Report', ComReg 20/93, 30 September 2020

[19] ComReg, 2019, 'Proposed Multi Band Spectrum Award- Response to Consultation and Draft Decision', ComReg 19/124, 20 December 2019

network that are hard to reach and cannot be connected using fibre including, for example, rural exchanges and hilltop sites.

The bands used for these links span almost the whole range of those available under the fixed links licensing regime (from 2 GHz up to 80 GHz), with the link length and capacity requirements varying significantly depending on the specific use/service. While many are relatively long range links in the 6 – 23 GHz bands, there are also short, high capacity links filling gaps in fibre networks (e.g. in cities), whereas others are used for low bandwidth island links that need to use frequencies in the lower bands.

2.1.6 Other use cases

Additionally, there are a number of users, each operating relatively few links, who do not fit neatly into the use cases described. These users operate primarily in the 11 – 23 GHz bands and have relatively low bandwidth requirements. They include:

- local authorities or government bodies;
- credit unions; and
- public safety bodies (e.g. gardaí, fire services).

> We would appreciate views from stakeholders on whether/how the bands that are important for each use case are likely to change in the near future.

2.2 Number of links

The following sections look at the trends in fixed links usage using ComReg's licensing data. This analysis is based on the details of individual links in ComReg's licensing database, in contrast some of the information published by ComReg at the level of the licensee.

In a number of places we disaggregate by 'user type', in particular looking at links operated by MNOs or FWA operators, where licensees are grouped based on ComReg's assessment of their main business case (although we only include links licensed to Meteor, and not Eircom, in the MNO category). User

type differs from use case, as a given operator of a certain user type may have links for multiple use cases.

'New' links increasingly make use of both polarisations

When looking at the data on number of links and bandwidth there are two ways of including the links licensed as dual polarisation links:

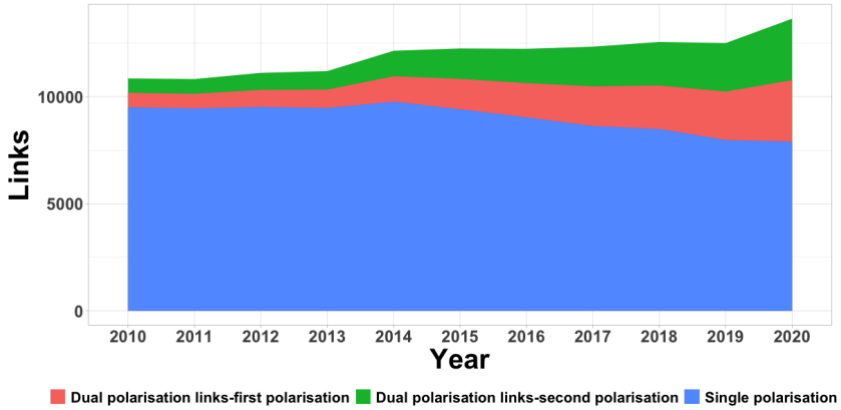
1. count those links as a single links – combined with the number of single polarisation licences this gives information about the number of links/routes in operation; or
2. count the dual polarisation links twice – this gives a more informative account of the bandwidth/capacity used (again in combination with the single polarisation links).

In the stacked charts below showing the number of links licensed over time:

- 'Single polarisation links' is the number of licences issues for use over a single polarisation;
- 'Dual polarisation links – first polarisation' is the number of licenses allocated for dual polarisation use – combined with the number of single polarisation links this gives the total number of links licenced; and
- 'Dual polarisation links – second polarisation' is the the number of licenses allocated for dual polarisation use again – stacked on top of the other two gives the total number of links counting dual polarisation links as two.

Figure 2 below shows the total number of individually licensed fixed links across all bands.

Figure 2: Total number of P-P links by year

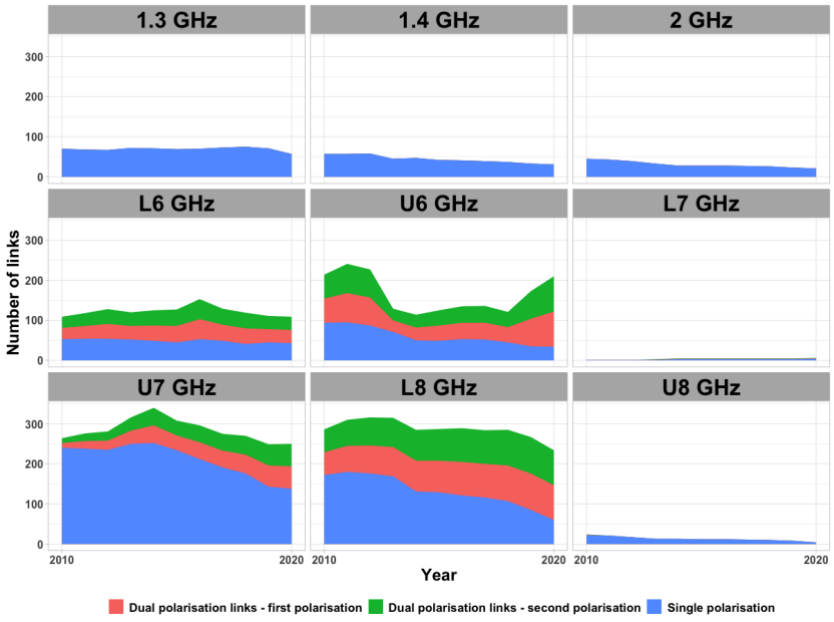


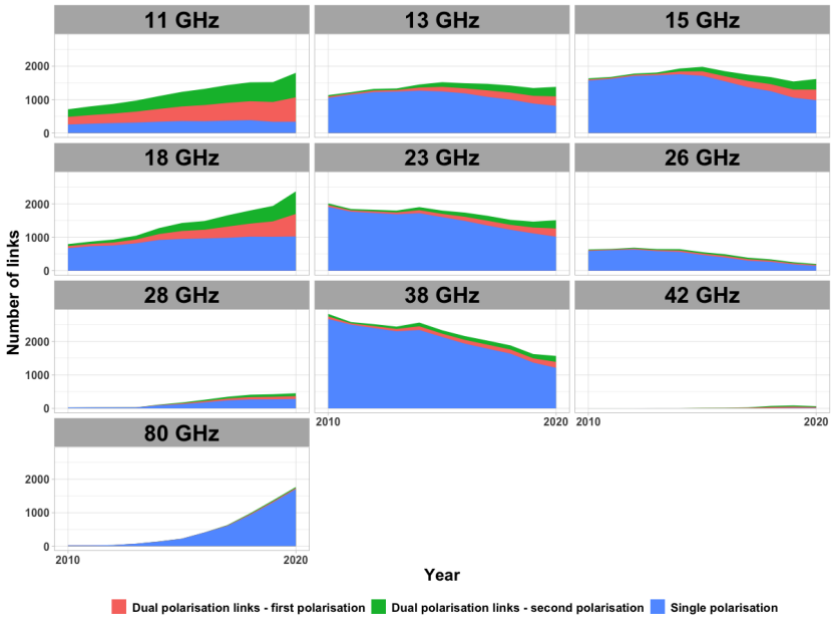
We can see that the number of individual fixed links licensed (i.e. counting a dual polarisation link as one) has been relatively

stable over time, but use of dual polarisation links has become much more common.

Stakeholders noted that their demand for bandwidth is increasing, and raised the point that operators are restricted in the bandwidth they can access with the widest channel widths available in certain bands. The data is consistent with this view, with operators using the second polarisation to double capacity over a given link, especially when wide channels are unavailable (e.g. we note that increased use of dual polarisation links started earliest in the 11 GHz band, where the largest channels are only 40 MHz). The increase in the number of dual polarisation links is also an indicator that the measures included in the fixed link guidelines (i.e. no charge for the use of the second polarisation, and compulsory use of dual polarisation for links in the same band on the same path) are effective in encouraging use of XPIC technology.

Figure 3: Total number of P-P links over time by band





The trend in usage varies significantly across bands. Nine 28 MHz channels have been available in the 31 GHz band since 2012, but there have never been any links in the band so it is not included in the graphs. Regarding the bands that are used, we notice that:

- there are relatively few links in bands below 10 GHz and this has remained largely constant over time;
- there is some use of dual polarisation links in the 6 GHz, 7 GHz and 8 GHz bands, but the number of these has also remained relatively stable;
- there has been growth in demand for links in the 11 GHz band, with new demand largely for dual polarisation links;
- there has been clear growth in demand for new links in the 18 GHz and 80 GHz bands;
- there are relatively few existing links in the 28 GHz and 42 GHz band compared to neighbouring bands, though there has been some increase in each;
- the number of links in the 26 GHz and 38 GHz bands has been consistently falling (although there does seem to be some increased use of dual polarisation links in the 23 GHz band in the last couple of years); and
- in the 13 GHz and 15 GHz bands, demand was steadily increasing until around 2016 when we see a sharp drop and then an increased use of dual polarisation links in recent years.

The broad picture is generally compatible with the view that demand is being shaped by:

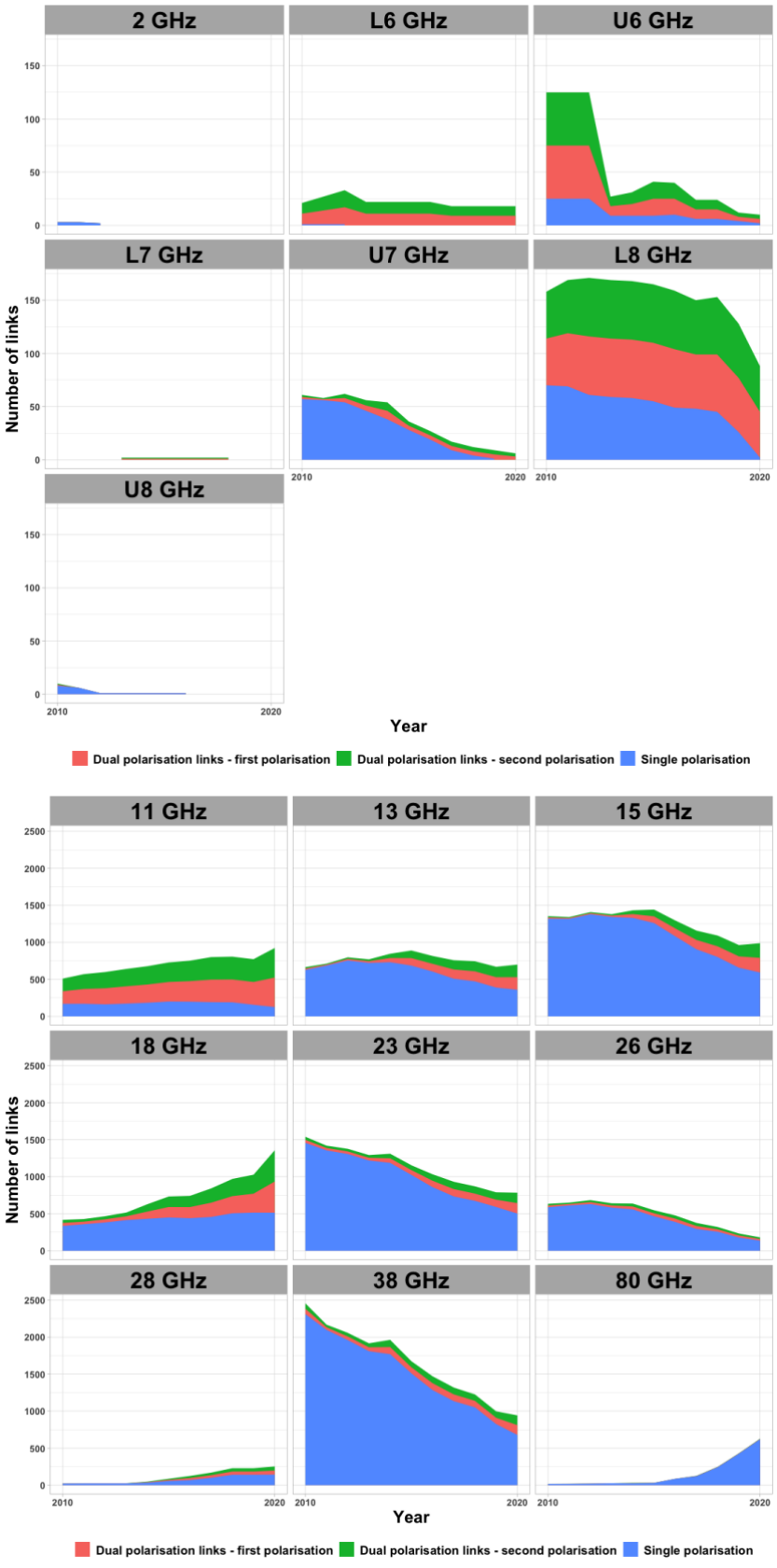
- an increase in capacity requirements and use of dual polarisation where wider channels are not available;
- some replacement of microwave links by fibre; and
- increasing bandwidth requirements shifting demand to higher frequencies, in particular the 80 GHz band (where link lengths allow) and also the 18 GHz band (where larger channels are available than in the 11 GHz, 13 GHz and 15 GHz bands).

However, we also note that the 13 GHz and 15 GHz bands have been closed to new applications in the congested area around Dublin since 2014. At the same time there will likely have been cancellations in those bands in the congested area (in particular if there is a need for some users to move into other bands where wider channels can be used) but with no scope other users to move into the vacated frequencies. This may then explain at least some of the decline in usage observed for the 13 GHz and 15 GHz bands in addition to the views above. If this is the case then continuing to not issue licences in the bands in the congested area could risk high value spectrum being unsused. The number of links declining is not in itself indicative of reduced use of the spectrum within the congested area as currently licences may still be modified to use a larger channel size (so the bandwidth available to new users may not actually increase even if the number of links licensed has fallen). However, we do also observe a fall in the bandwidth used in the 13 GHz and 15 GHz bands within the congested area, which would indicate that there is more spectrum available than when ComReg ceased to issue new licences.

Number of links licensed to MNOs

Figure 4 shows the evolution of the number of individual link licences held by the MNOs (collectively) over time.

Figure 4: Number of MNO links by band over time



We can see that growth in the number of MNO links appears to be strongest in the 18 GHz and 80 GHz bands. In particular, the 80 GHz band offers access to a very large amount of bandwidth (with 1000 MHz channels available) for high capacity links where the required link length is sufficiently short. Where longer links are required, the 18 GHz band offers 112 MHz channels and may be a good substitute for the 11 GHz band (where the largest channels available are 40 MHz) and the 13 GHz and 15 GHz bands (where the largest channels available are 56 MHz, and new links are no longer allocated in the congested area).

However, overall, the number of individual link licences held by MNOs is falling (this is shown more clearly in Figure 14 in Annex C), in particular:

- in the 13 GHz and 15 GHz bands, where new links are no longer accepted in the congested area and where channels widths only go up to 56 MHz; and
- in the 23 GHz, 26 GHz, and 38 GHz bands.

As discussed above, the reduction in the 13 GHz and 15 GHz bands may be caused by a combination of a need for wider channels, replacement of links with fibre, and ComReg ceasing to license links in the bands around Dublin.

A fall in demand in other bands (23 GHz, 26 GHz and 38 GHz) may be a result of the MNOs migrating individually licensed links into their block license where possible, which would reduce their overall spectrum licence fees. With this in mind, we must remember that the MNOs all have access to these 26 GHz block licences, so a reduction in demand for individual link licences does not necessarily represent a fall in overall demand for fixed links – we discuss use of the 26 GHz block licences further below.

Three held fixed links across two networks following its merger with O2, but it consolidated these between 2018 and 2020. This may also have contributed to the fall in MNO links.

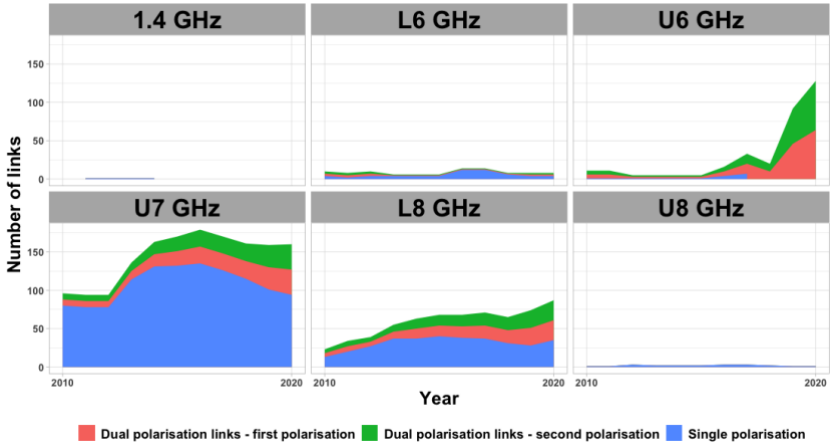
Individual link licences held by FWA operators

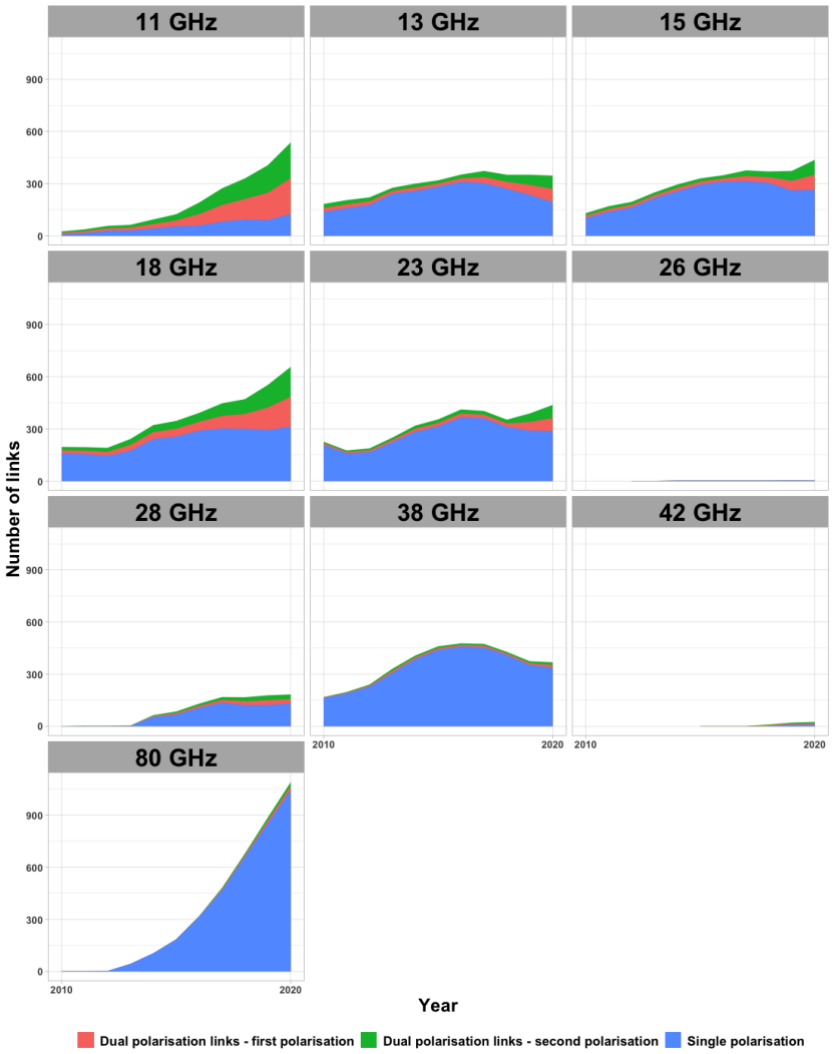
Figure 5 shows the evolution of the number of individual links licences held by the FWA operators (collectively) over time.

The total number of links licensed to FWA operators is growing quickly (see Figure 17). Although this positive trend is apparent in most of the fixed links bands, it is most noticeable in the 80 GHz band, which we would expect to be related to wireless delivery of short hops from fibre-connected nodes. However, we also see strong growth in demand for links in the 18 GHz and the 11 GHz bands, as well as increased use of the 23 GHz and 28 GHz bands .

There also appears to have been a marked increase in the use of dual polarisation links. While the number of FWA links (overall) has been increasing, growth in the number of single polarisation links seems to have fallen off since 2017, suggesting that new FWA links are typically deployed with dual polarisation. Again this is shown more clearly in Figure 17.

Figure 5: Number of FWA operator links by band over time





Interim conclusion

In summary, while there has not been a large change in the overall number of individually licensed links, we can see clear trends towards:

- increased use of dual polarisation links;
- increased importance of the 18 GHz and 80 GHz bands; and
- more new individual links being licensed to FWA operators compared to MNOs.

2.3 Bandwidth

Upwards trend in bandwidth used, clearest in the 80 GHz band

Demand for fixed links is not fully captured by trends in the number of links in each band if additional demand derives from the need for extra capacity over a given path, rather than the need to connect more sites:

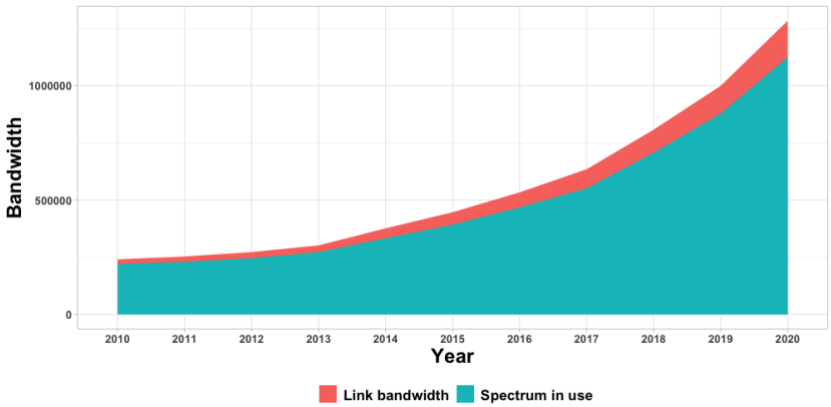
- increasing use of dual polarisation links and increases in the number of links in bands where more capacity is available (i.e. 80 GHz), discussed above, suggest this is the case;
- stakeholders noted that, in the past, there was a move from 28 MHz to 56 MHz channels, and there is now demand for 112 MHz channels, especially if this is a change to applications within a band, it will not be observable in the number of links; and
- increases in some bands and decreases in others could be caused between switching between bands, but increases in bandwidth at the same time suggests that demand is increasing.

Therefore, we also look at trends in the total bandwidth associated with individually licensed links (i.e. by summing the channel width licensed across links).

Figure 6 shows the evolution of total bandwidth licensed across all fixed links over time, where:

- 'Link bandwidth' refers to the total number of MHz available to each user (counting the bandwidth of a dual polarisation link twice); and
- 'Spectrum in use' does not include the bandwidth of the second polarisation, so represents the bandwidth associated with the allocated frequency ranges.

Figure 6: Total bandwidth (MHz) in use over time



We see clearly that, in line with expectations and feedback received from stakeholders, the total amount of bandwidth used with individually licensed fixed links is growing strongly. We see for example from Figure 7 and Figure 8, that this is largely driven by the 80 GHz band where 1000 MHz channels are available (but use of dual polarisation links is uncommon)

and geographically with the greatest increase in Dublin (Figure 24 in Annex C). Bandwidth is also increasing in many of the other bands from 11 GHz upwards. It is stable, or increasing only slightly, in the 13 GHz and 15 GHz bands, where additional bandwidth appears to be achieved by use of the second polarisation over a channel rather than with new links.

In the above discussion of trends in the number of links we note that there is a fall in the number of 13 GHz and 15 GHz links (over 10% since 2014), and we would be concerned that, as a result, spectrum in the bands might end up inefficiently unused in the congested area. Of course, a fall in the number of links does not necessarily imply that spectrum is left unused, because the remaining licences can be amended to cover wider channels, such that it is possible that the total bandwidth across the links does not fall significantly (i.e. the number of links falls, but this is offset by an increase in average bandwidth on a link). However, when looking at the trends in bandwidth, we see that it is indeed the case that use of the spectrum in the 13 GHz and 15 GHz bands is decreasing in the congested area (on links with at least one end in the congested area, it has fallen by around 60% since 2014). Figure 32 and Figure 33 in Annex C show that spectrum in use on links with one or both ends in the congested area is falling. Therefore, we are concerned that cancellation of existing licences could lead to spectrum going inefficiently unused in the future if the bands remain closed to new applications in the congested area.

Again, increased bandwith usage is primarily driven by the MNOs and FWA operators. The trends for these user types are qualitatively similar, and in both cases there are rapid increases in bandwidth, facilitated largely by increased use of the 80 GHz band.

Figure 7: MNO bandwidth (MHz) by band over time

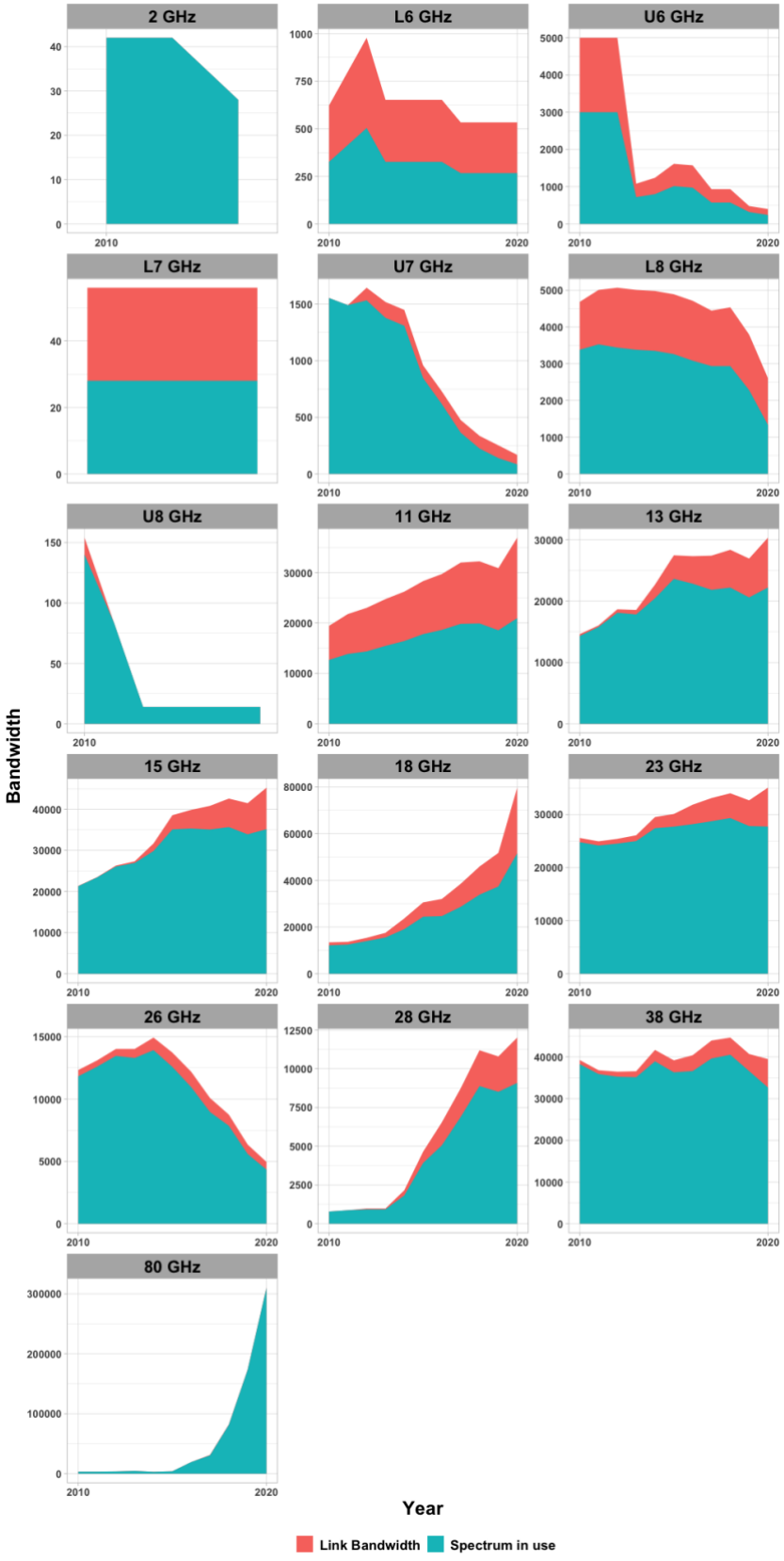
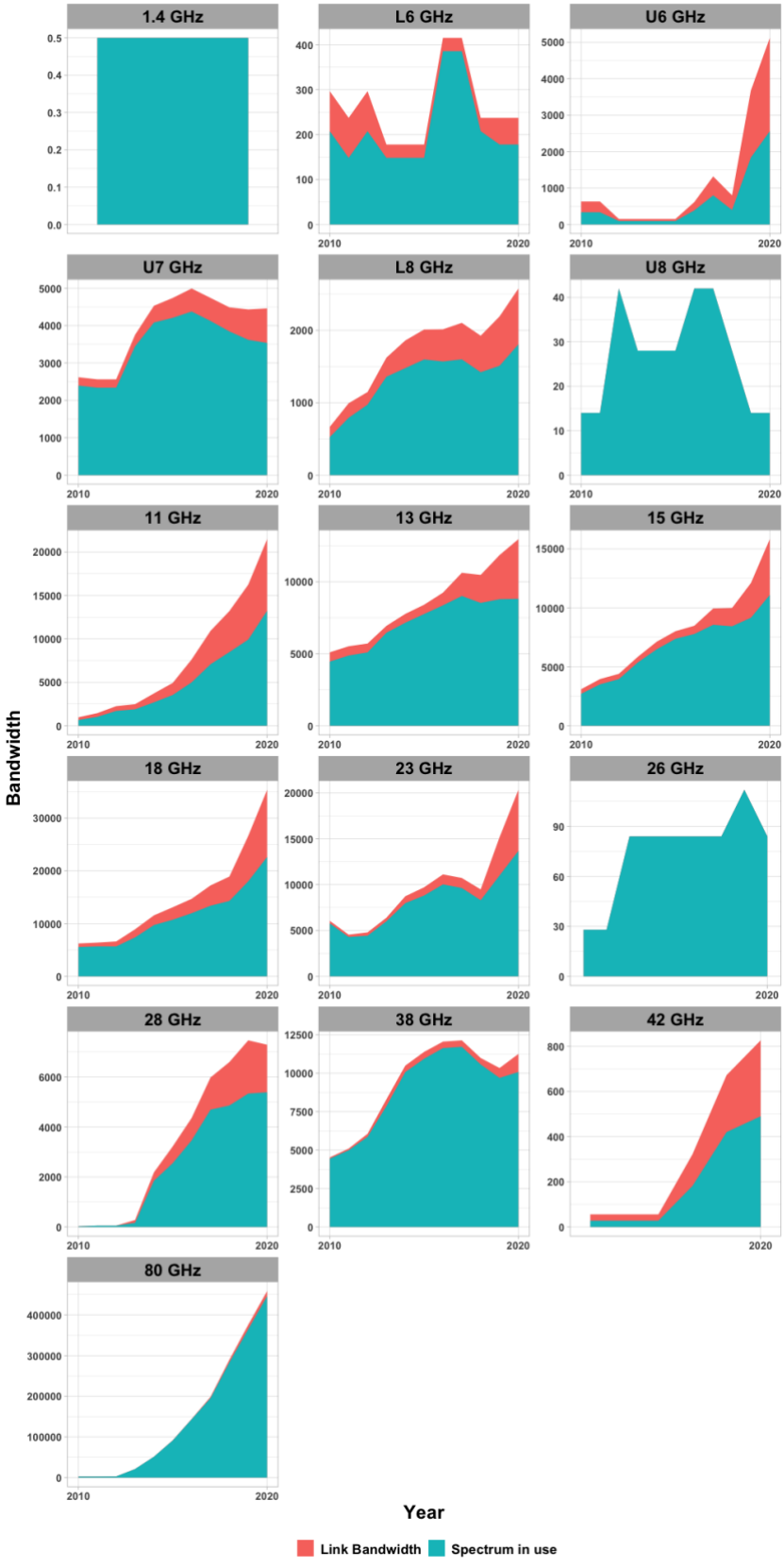


Figure 8: FWA operator bandwidth (MHz) by band over time



Our understanding is that users concentrated in the sub-10 GHz bands typically have not had the same need for increased capacity as the MNOs and FWA operators. The consensus from the RFIs is that some users already have sufficient bandwidth, with typical use cases in the bands (such as broadcasting and telemetry) generally more concerned with reliability and link length than speed/capacity. Unsurprisingly, links for use cases that prioritise high availability and the ability to cover long distances have not seen a significant need for greater bandwidth. Some of these stakeholders expect their demand for fixed links to fall in the future, but they have expressed uncertainty over when and to what extent this will happen, because they believe the amount of fibre that will be available is uncertain.

Interim conclusion

Overall, there is a strong upwards trend in the total bandwidth across fixed links, facilitated by increased use of the 80 GHz band, and driven mostly by MNOs and FWA operators requiring more capacity per link on average.

2.4 MNO use of block licences

The three MNOs each have access to five 2×28 MHz spectrum lots in the 26 GHz band until 2028. Where they can be used for particular links, it is likely to be more economical to use block licences (where licence fees are fixed and there is no additional fee for new links) over individual link licences (where fees are paid per link). Using block licences wherever possible also helps to reduce the cost of holding spares, and allows for deploying new links quickly when needed. Therefore, it is likely that the MNOs would:

- migrate existing individually licensed links (in the 26 GHz and 38 GHz bands etc.) into their block licences when technically feasible and economical viable to do so; and
- deploy new links in their block licences, where possible.

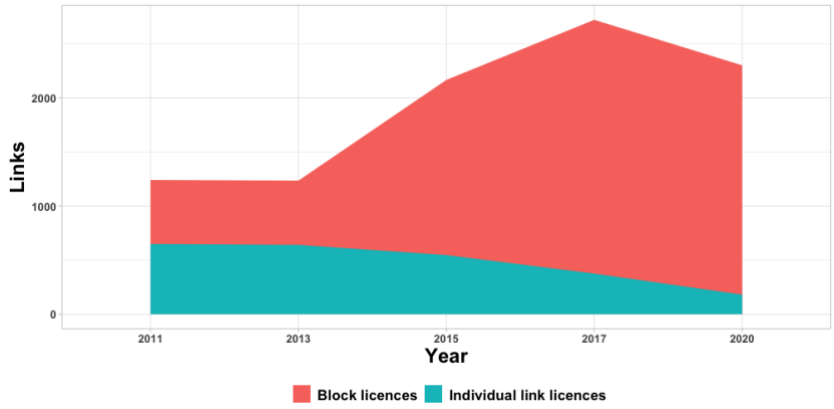
Site registrations on the block licences have increased over time, offsetting the decline in links individually licensed to MNOs. This trend slowed in the run up to the recent 26 GHz award, but is observable both before and afterwards (Vodafone and Three already held block licences from 2008, however all three MNOs hold more blocks than they did prior to 2018). Therefore, part of the fall in demand for substitutes to the

26 GHz band (e.g. 38 GHz), is visible before the recent award but accelerating afterwards, and is likely explained by MNOs migrating links onto their block licences.

The stakeholder interviews make clear that demand for bandwidth from the MNOs is increasing strongly. The combination of the MNOs' statements in stakeholder interviews, the increasing bandwidth on their individually licensed links, and their preference for using their block licences, means we are confident that the demand for fixed links from MNOs is trending strongly upwards.

Figure 9 assumes that the number of links on the block licences is half the number of sites. This is a conservative estimate; if any sites have multiple P-P links connected to them, then the actual number of links on the block licences will be higher. In any case, it shows that the number of MNO links in the 26 GHz band is has increased considerably over the last ten years, once the block licences are taken into account.

Figure 9: MNO links in the 26 GHz band (block and individual licences)



Interim conclusion

Therefore, mobile backhaul is likely to remain the most common use case, even if the trends visible in individual link licences are not as pronounced as those for FWA.

2.5 Typical link lengths and bandwidths

Figure 41 in Annex C presents the distributions of link lengths on live licences at the end of June 2020, by band. It shows the expected negative relationship between average link length and frequency, enforced by the physics and ComReg's minimum path length restrictions. For example, links are around 40 km in the 6 – 8 GHz bands, but mostly less than 2 km in the 80 GHz band. However, there is a significant amount of variance in the distributions for each band, probably driven by area specific

constraints such as the location of key high sites relative to sites where there is high demand.

ComReg licenses channels of up to 112 MHz in some of the available bands up to 42 GHz, though the maximum available channel size is smaller in some bands, based mostly on CEPT/ECC recommendations (as summarised in Annex A.1.1). The histograms of channel width by band, by year in Figure 42 show the move to wider channels mentioned by stakeholders in the interviews (e.g. 56 MHz channels gradually becoming more common than 28 MHz channels in the 23 GHz band).

Defragmentation to remove unusable "gaps" given bandwidth growth

Under the current link licensing regime, operators – whether inadvertently or deliberately - could choose channels within a band, over a certain path, that fragment the remaining free spectrum into blocks that are unusable by others needing a minimum bandwidth, when an alternative arrangement could allow for larger and more attractive blocks of contiguous spectrum. There is therefore a risk of inefficieny where currently unused spectrum cannot be used to its full potential by higher bandwidth users, even if there is enough spectrum available overall, and this is potentially a concern in light of the observed growth in demand for bandwidth.

To assess the extent to which fragmentation might already be an issue, we have conducted a high level analysis to form a consertvative estimate of the degree of fragmentation in each of the fixed links bands. This is discussed in further detail in Annex C.8, but in summary we find that:

- fragmentation is not a concern in the sub-10 GHz bands, where links cover long distances and bandwidth requirements are stable;
- there is a limited amount of fragmentation in the 11 GHz band, but not enough to present a material convern based on our pessimistic measure;
- there is evidence to suggest that fragmentation might be a problem in the 13 GHz and 15 GHz bands, in particular with regards to assigning the larger 56 MHz channels;
- in the 18 GHz to 28 GHz bands there appears to be some fragmentation, predominantly around Dublin and Cork, but to a lesser extent than in the 13 GHz and 15 GHz bands;
- in the 38 GHz and 42 GHz bands fragmentation does not seem to be an issue at present; and
- interference in the 80 GHz band is very localised, and while fragmentation could arise in some parts of the

cities if there was demand for very wide (i.e. 2000 MHz) channels, we are not concerned about fragmentation in the band at present.

Where fragmentation is identified as a potential issue, we anticipate that in order for ComReg to address this under the current individual link licensing regime it would likely need to direct new licensees to specific frequencies, rather than simply allowing licensees to select any vacant frequency at the relevant location.

Interim conclusion

However, there is limited evidence that fragmentation is an issue currently, and therefore there is little need for ComReg to change its licensing procedure to deal with fragmentation, and no grounds for it to undertake a complicated reorganisation of existing links.

We would also appreciate comments from stakeholders on:

- whether fragmentation has been a problem in practice; and, if so
- any views on potential (and viable) solutions.

2.6 Congestion and geographical clustering

Congestion occurs when many links are using the same band along similar paths, to the point where spectrum becomes scarce and it is difficult to fit new links in that area. Therefore, congestion is:

- dependent on users' ability to switch frequencies, within a band or across bands (i.e. is based on a long-run view of spectrum available prior to users committing to certain network equipment that may constrain their ability to switch frequency in the near term);
- dependent on the detailed characteristics of links, especially location of end points.

A reasonable working definition of congestion for a band at a particular location is that there is a low probability of being able to license a 'typical' link (in terms of power levels and likely

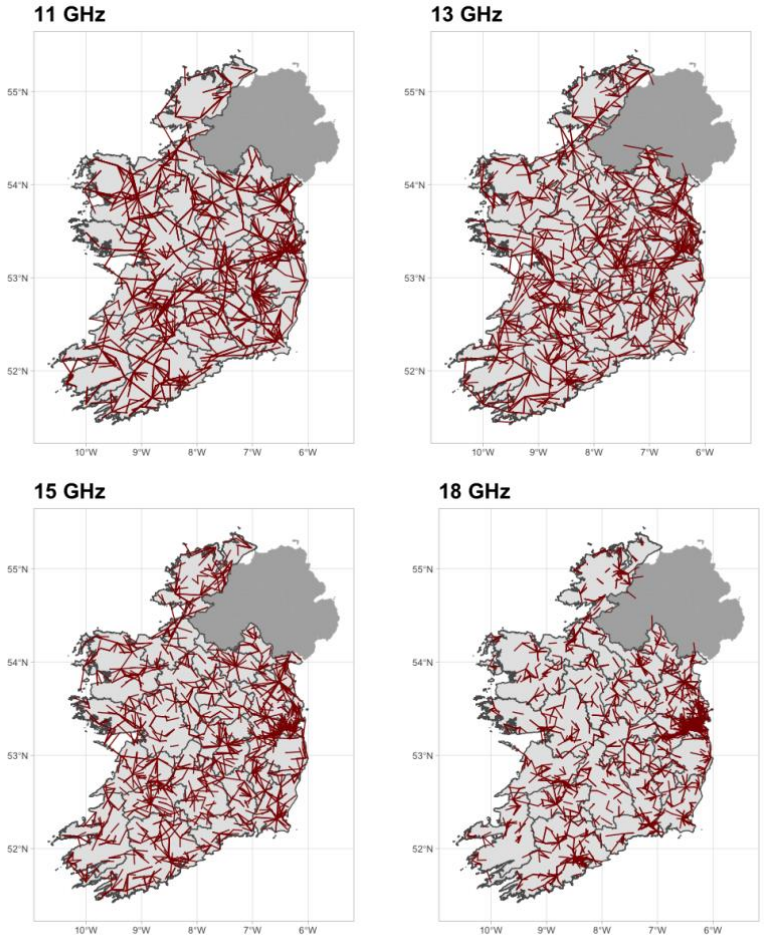
bearings from that location) within a band or adjacent bands with broadly similar propagation characteristics. Clearly formalising this definition would require some assumptions about likely demand for fixed links with one end at that particular location. For instance, the locations of fixed links are driven by the underlying connectivity requirements for end users, but also constrained by the geography (i.e. high site availability and coastline may tend to cause demand to cluster around particular bearings from that location).

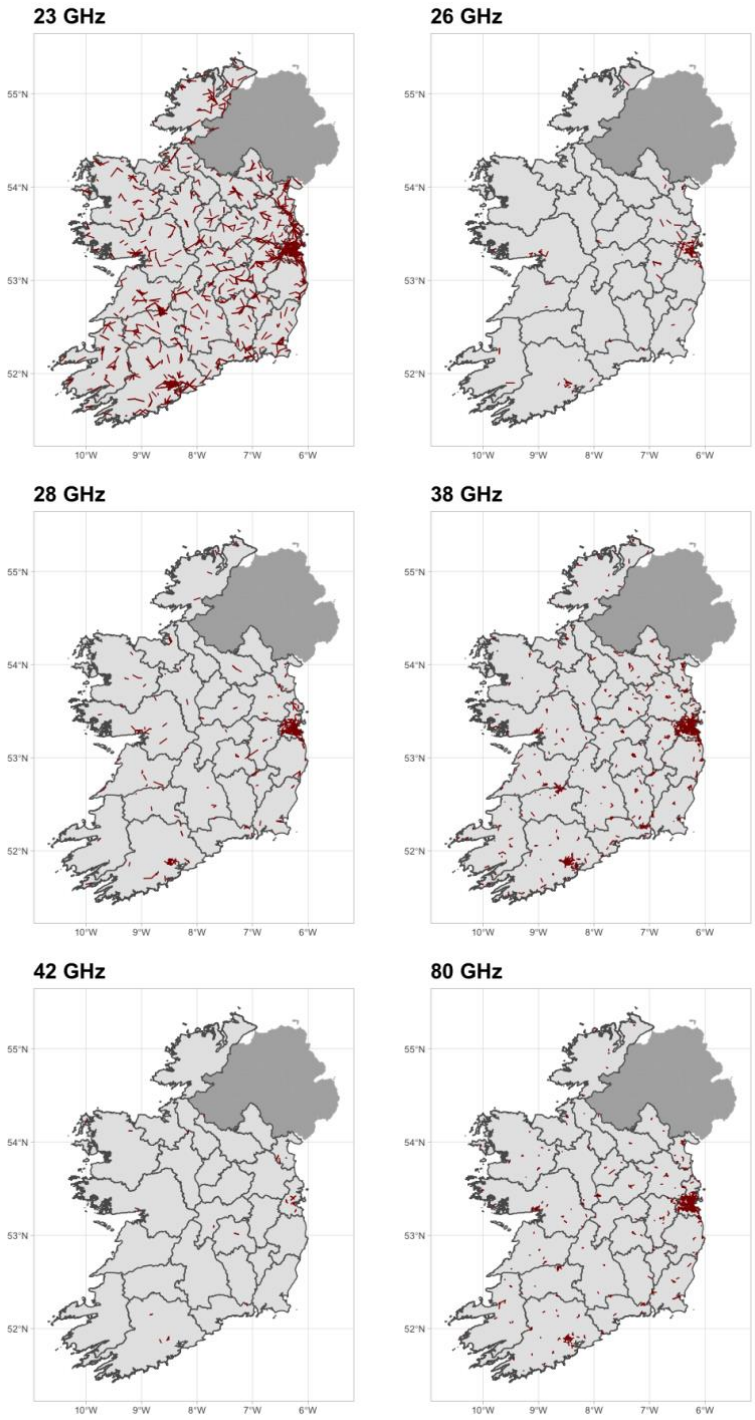
Because of the possibility of users switching frequencies (at least viewed over the long run, as discussed in detail below) and because of clustering of where fixed links are deployed, at many locations there is no congestion and we do not expect congestion to develop. Where congestion occurs, it is limited to specific locations, but this is likely to worsen if there is increased demand for wider channels for greater bandwidth.

Congestion tends to occur due to location specific factors that concentrate at least one end of the links onto the same point. The high usage of the 13 – 23 GHz bands in the Dublin area appears to be largely a result of there being a limited number of high sites around South Dublin (e.g. Three Rock, Tallaght, RTÉ Donnybrook) with a good line of site into the city; these sites are, therefore, very popular with operators. The congested bands are those that offer a good balance of available bandwidth (to meet speed requirements) and link lengths that can reach from the high sites into the city without the need to build intermediate sites.

Given the increasing demand for bandwidth outlined above, and the fact that some use cases may be more prevalent in urban areas and along certain paths, we look at the current distribution of fixed links for evidence of clustering that could lead to congestion. 'Geographical clustering' refers to a large proportion of the fixed links in a band being in the same area. The size of the area referred to depends on the path lengths achievable by the particular band, so it is smaller at higher frequencies. Geographical clustering is observable in the maps below, whereas congestion occurs only when the links in a geographical cluster cause spectrum scarcity, because they use a significant fraction of the bandwidth available, with links on similar paths, such that they preclude many new links being installed in that band, at that location.

Figure 10: Geographical clustering





The maps show the 2020 live licences for the bands from 11 GHz upwards, where geographical clustering is most likely to occur. The sub-10 GHz bands are less susceptible to congestion as the links are longer and not concentrated in particular areas, and because demand for banwidth at those frequencies is relatively low and stable.

Each link is plotted as a line between its two sites. The number of links and the average link lengths are the same as described

above, and there is clear clustering of links in Dublin for most of the bands from 18 GHz upwards, however we also note that there is:

- geographical clustering in other cities, particularly Cork; and
- the trends towards use of higher frequency bands, demand for greater bandwidth, and very localised use cases mean this could potentially translate into congestion in the future.

ComReg currently applies a congestion charge only for links in the 18 GHz and 23 GHz bands in the congested area, but the trends suggest it may be beneficial to formalise a measure of congestion either to make the congestion charging dynamic, being turned off/on when the measure of congestion crossed a threshold, or simply to provide more information for potential users to understand when bands may become full at a particular location and alternatives need to be considered.

Clustering is still visible in the 18 GHz and 23 GHz bands in Dublin, but this does not mean that the charge is necessarily too low. Instead, it could be that it has not been in place long enough (asset life of equipment exceeds the three years of congestion charging, and the charge should only target long run opportunity cost). It has also not been applied in isolation; closing the 13 GHz and 15 GHz bands may have led operators to use the other congested bands, even though there is congestion charging.

To be clear, neither the evidence of geographical clustering here, nor the increases in demands for bandwidth, imply that there will be congestion. In practice, there may be a greater number of paths into other cities, or interference may be very limited between the short links used within cities. Formalising a measure of congestion might nevertheless be useful in clarifying how ComReg views congestion, and the probability that a given application will be accepted going forwards.

Interim conclusion

In summary, we have not identified any significant congestion outside of Dublin, but ComReg should consider how it monitors congestion throughout the country, as it is possible that increasing bandwidth demand will lead to congestion in future.

2.7 Use of licence-exempt spectrum

The RFI responses confirm that the main use case for licence exempt spectrum is providing low cost broadband access (i.e. the P-MP instance of FWA set out above). The responses also suggest that the 5 GHz band was by far the most widely used licence exempt band, followed by 17 GHz, reflecting the greater amount of spectrum available in the band and the maturity of uses at those frequencies relative to 60 GHz.

FWA links were the most common use case, though there were also a small number of fixed network links, corporate users, and telemetry applications. Within these use cases, operators who use licence exempt spectrum are:

- more sensitive to price; and
- more likely to be based in rural areas.

On the other hand, the MNOs had no interest in unlicensed spectrum.

The lack of interference protection that comes with the bands is only suitable for use cases that are relatively less concerned with interference, and more with the opportunity to avoid fees and quickly deploy new links. This may appeal to users providing a low-cost service to customers, rather than those with stringent service level agreements (SLAs). These users trade off interference protection against the time and financial costs of the licensing process. Naturally, interference issues are limited in rural areas, so most licence exempt links operate outside of the five cities. However, some users judge interference issues to be too great even in regional towns.

Operators' use of the licence exempt bands and their expressed opinion that licence fees limit use of the main fixed links bands suggest that the demand for other bands could increase significantly if licence fees were lower. However, there is little evidence of licence fees affecting a user's choice of band in most cases, possibly because the difference in fees between bands is small, especially relative to equipment costs for example. Most of the stakeholder interview participants have a link length policy for choosing bands.

Operators' RFI responses suggest that if operators who rely on licence exempt spectrum had – hypothetically – to move out of the 5 GHz band, they would:

- consider the 17 GHz or even 80 GHz bands where link lengths permit (the latter is licensed, but fees are relatively low); and conversely
- reducing fees in neighbouring bands would lead operators to move out of the 5 GHz band, into one where they could achieve higher throughput.

These operators prioritise fees and speed of rollout more than others. It was noted in the interviews that this can bring a significant cost advantage, but the stakeholders who hold a large number of links are less sensitive to price, more concerned about interference and have greater capacity requirements.

New demand for licence exempt spectrum likely concentrated in the 60 GHz band

ComReg does not routinely collect data on the total number of fixed links in the licence exempt bands, but operators have provided information on the number of fixed links through their RFI responses (though this may underestimate the total use of the bands). According to these RFI responses, the number of links deployed in each of the 5 GHz, 17 GHz, 24 GHz, and 60 GHz bands has increased since 2016, however the number of:

- 5 GHz links fell from 2018 to 2019; and
- there are still far fewer links in the other three bands.

Fibre to the premises (FTTP) is expected by some operators to be an alternative to FWA, and other low bandwidth, low cost applications could be met by mobile. While there is still considerable uncertainty around this, some RFI respondents have already switched a number of 5 GHz links onto fibre, though there may also be some switching into licensed bands.

Some users increasingly prefer the 17 GHz and 24 GHz bands to the 5 GHz because:

- there are significantly fewer links in the bands, so interference issues are less frequent; and
- licence exempt spectrum users are more likely to choose bands on a cost basis, rather than a link length one, so they are more likely to be able to tolerate the difference in propagation characteristics between the bands.

Therefore, it seems these three licence exempt bands are close substitutes from the point of view of the operators who can use licence exempt spectrum. In turn, this means that the trends in use of the lower licence exempt bands will be closely related, although the level of use remains different. There is slightly more spectrum available in the 5 GHz band than the others (355 MHz compared to 200 MHz and 250 MHz in the 17 GHz and 24 GHz bands respectively), however it is fragmented, so there is a

limit on the amount of bandwidth growth that is feasible in these bands.

On the other hand, trends in the use of the 60 GHz band will be different, because the use cases are very different to those in the lower bands. We do not have a clear quantitative picture of 60 GHz trends from the RFI data, but operators have specifically expressed an interest in more spectrum being made available at 60 GHz on a licence exempt basis, and we expect that the band will increase in importance due to growth in demand for higher bandwidth links.

In the following section, we describe new use cases in the 60 GHz band that will use advanced technologies to provide high capacity services over short distances (e.g. because the propagation of 60 GHz waves is limited by oxygen-absorption attenuation). These links are unlikely to face the same interference problems as those in the traditional fixed links bands, because of the short path lengths and oxygen absorption at these wavelengths. Considerably more links are likely to be deployed in the band over the coming years as these use cases develop.

Interim conclusion

In conclusion, we believe that the 5 GHz, 17 GHz, and 24 GHz bands are all important for some FWA services in rural areas, whereas the 60 GHz band may become increasingly important developing use cases using advanced technologies.

3 Emerging and future trends for use cases

The previous section is primarily based on ComReg's licensing data, which shows that the main trends in fixed links demand in Ireland so far are:

- requirements for greater bandwidth, driven by a subset of use cases (i.e. mobile backhaul and fixed wireless services); and
- an increasing proportion of links in higher frequency bands, where more spectrum is available.

Emerging trends may not yet be visible in the data but have been identified through stakeholder interviews, RFIs, and desk research. In general, these sources agree with the trends identified in the data, so we expect these trends to continue. Stakeholders have, however highlighted some issues that may change (slow or accelerate) these trends over the next ten years.

3.1 Continued increases in bandwidth

The most important trend visible in the data is a consistent increase in the total bandwidth in use across all fixed links. The stakeholder interviews indicate that this trend is likely to continue, and they provide more detail on the speeds that end users demand, with the standard moving towards 1 Gbps (projected to be even higher in some urban use cases within the next five years).

The trend towards greater bandwidths is present throughout Europe, according to the responses from BEREC members to ComReg's RFI (though the speed of growth varies).

Increasing average link capacity

To support higher capacity services, operators need greater bandwidth on the same paths rather than more links. Therefore, operators are likely to move towards using links at higher frequencies, on average, where more spectrum and large channels are available. Links in these bands will necessarily be shorter on average, because of the propagation charateristics of the spectrum, but shorter links will be required, for example as fibre reach increases.

Another factor that will contribute to the trend towards shorter, higher capacity links on average is changes to the fixed links use

cases. There may be changes to network structures characterised by dense deployments of high capacity links in urban areas, for example:

- small cell mobile backhaul networks;
- advanced fixed wireless services; and
- new P-MP applications, especially at 60 GHz (e.g. to connect multiple users in business parks, with link lengths around 500 m).

3.2 Fibre roll-out and fixed links demand

Many use cases might potentially be served with fibre instead of microwave links. However, we do not expect fibre roll-out, including to rural areas, to eliminate the need for fixed links. Indeed, we heard some suggestions during our interviews that fibre rollout may increase demand for fixed links to extend the reach of fibre networks.

3.2.1 National broadband plan and rural fibre

The NBP is intended to provide high quality and reliable broadband services in rural areas where a competitive deployment of FTTP and fibre to the cabinet (FTTC) is not expected to be commercially viable. Under this program, the Government has identified an intervention area for which it will provide funding to a commercial entity to support the build of such a network and associated backhaul network infrastructures. The NBP aims to provide fibre for all premises in the intervention area within the next 7 years.

Where covered by the intervention area, this program will provide readily accessable fibre in rural areas of Ireland providing operators with suitable alternative to fixed link bands. However, the NBP milestones, set on a number of household covered per year, in combination with a required wide coverage may not align for effective/efficient use of the fibre network by fixed services operators in rural Ireland, at least in upcoming years.

The NBP is a targeted intervention, subsidising roll-out of fibre services in a defined intervention area where they would otherwise be uneconomic. The subsidy is intended to support wholesale broadband services for residential and business

customers. NBI has been appointed to provide these services within the intervention area.

We would not expect additional fibre roll-out in the intervention area resulting from the NBP intervention to provide a direct substitute for fixed links. NBI's obligations are to provide services to support primarily residential broadband services and do not include obligations to provide wholesale services appropriate for carrier-grade connections.

Alongside the NBP intervention within the intervention area, Eir has recently deployed additional fibre (as a GPON network) within certain rural areas outside the intervention area. This may provide some additional opportunity for fibre-based backhaul services to be provided to other network operators, including NBI who may require such services to interconnect the patchwork of geographical areas within intervention area. Therefore, this development may improve fibre-based coverage for other network operators' backhaul within certain rural areas, either as shared capacity within a GPON or as point-to-point fibre links where additional dedicated fibre is installed alongside a shared optical network.

3.2.2 Substitution of fixed links by fibre

For the reasons above, we do not expect the NBP to slow or reverse the trends in fixed link demand, but in general fibre roll out may not directly substitute for fixed links in any case. In many applications, deploying fibre to remote sites could be very costly. Even where fixed links can be replaced with fibre, they might be kept for redundancy (e.g. in core networks or for business connectivity as a way of guaranteeing sufficient availability), as the links are relatively inexpensive and can offer high availability (for example, being immune to being cut by street works, unlike fibre). Therefore fibre's main effect will be on the characteristics of fixed links, shifting demand towards higher capacity, shorter links.

Shorter fixed links at the edges of fibre networks

Firstly, this is because there is a large number of sites that we cannot expect fibre to reach, either because it is infeasible or excessively costly. These sites are found both in urban and rural areas, but in both cases there will be a requirement for fixed links to connect terminal sites to the fibre network.

In cities, we expect there to be a increasing number of sites, in close proximity to each other, that need to be connected using either fibre or microwave links (e.g. for mobile backhaul). In

many cases it operators will not be able to get permission to install fibre to each of these sites, and even if it was permitted it would likely be prohibitively expensive. Therefore we expect that users would instead connect these sites with fixed links. However, these links would only need to cover short distances, as installing fibre at some point nearby is likely to be economically viable.

We also expect that the reach of fibre networks will expand in rural areas, although it will remain infeasible or economically unviable to reach some sites (e.g. some mountop sites). Fixed links will still be needed to reach these sites, but will only need to reach to the edge of the expanded fibre network, so the average link length required in rural areas will fall. Moreover, we might expect increased business activity outside of the cities as a result of the increased fibre presence. In this case, there would be more isolated business users that needed to be connected with relatively short fixed links.

Fixed links as backup to fibre connections

Secondly, even over paths where it is possible to install fibre, we would not expect fixed links to be replaced entirely, though the total number needed may fall. This is because operators value reliability and therefore will keep fixed links for backup. In some cases, the operator will prefer to have different types of connection (i.e. land/air redundancy), or will not be able to install a second fibre connection following a different route. If both connections were fibre cables following the same paths, then the risks of them being disrupted would be correlated and as a result one would not be effective backup for the other.

As we have outlined, fixed links are also preferable to fibre as a backup connection because they are cheaper. An operator who is technically able to install two fibre connections is unlikely to be willing to incur the cost of a second fibre connection, especially as the benefit of fibre over a fixed link would be small when the link is for redundancy and will seldom be used.

Timeframe for fibre's effect on fixed links

While most operators agree that the main effect of fixed links will be a decrease in average link length, and at most a modest decline in the number of links, they have expressed a broad range of views on the time frame over which the effects of fibre will be seen. Some have explicitly referenced the uncertainty over when fibre will be available. Typically, operators with their own fibre networks are more optimistic about when fibre will be available, but other operators do not expect enough fibre to be available for its effect on fixed links to be large for some time. Stakeholders have also taken a range of views on how the NBP will affect the timing of fibre rollout, with some noting that NBI

will need a significant number of fixed links in the early stages of the plan.

Interim conclusion

In any case, we note that the the effect of fibre leading to shorter average link lengths is likely to coincide with the general increase in demand for bandwidth on fixed links. Both of these factors mean that operators will increasingly prefer higher frequency bands, and that fibre will make it feasible to use these to provide higher capacities in more cases, because a greater proportion of links only need to cover relatively short distances.

3.3 Wider channels in existing bands

In the licensing data, we have seen a move towards greater average channel widths within certain bands over time (typically 28 MHz channels to 56 MHz channels). Naturally, there is a limit to how far this trend can continue imposed by the channels that are on offer, as set out in ComReg's band plans.

However, we expect that the increase in demand for wider channels will continue, both because it is consistent with the general increase in demand for bandwidth discussed above, and because of opinions expressed in the stakeholder interviews.

Some parties expressed an interest in larger channels being made available in some of the bands in light of growing capacity requirements. In particular, there seems to be demand for larger channels in the 13 GHz and 15 GHz bands where the maximum bandwidth on offer is only 56 MHz (compared with channels of at least 110/112 MHz channels in the majority of the higher frequency bands). The fact that only 40 MHz channels are available in the 11 GHz band, meaning they are unlikely to use the band for high capacity services was also raised, however, even 80 MHz channels would still fall short of what some operators would ideally have access to, so the focus was on channels in the 13 GHz and 15 GHz bands. Some operators would vacate the band in favour of higher frequency ones where 112 MHz channels are available, if there are no changes to the band plans, but others would not be able to do so as they find it easier to move down frequencies than up.

Interim conclusion

Only a few of wider channels could be accommodated in bands such as 13 GHz and 15 GHz where there is limited spectrum available, and ComReg should not depart from its general principle of following international harmonisation measures without good reason. However, we note that the most recent

ITU-R recommendation for the 15 GHz band (which ComReg uses) includes 112 MHz channels[20], and ComReg's updated fixed links guidelines should consider this.

3.4 Spectrum efficient technologies

There are a number of technology developments that can help to improve the efficiency of spectrum usage (i.e. achieve more capacity per MHz). Some of these have been available for some time, while others are only recently commercially available or are in development.

We understand that operators' general preference for achieving a certain capacity over a link is to have access to a sufficiently wide channel of contiguous spectrum. This is the simplest solution and allows for using more basic equipment that is typically cheaper. However, it is not always possible to accommodate such large channels in a given band, either because:

- there is simply not enough bandwidth available within the band(s) that would be suitable for achieving the link length required; and/or
- existing licences have not left enough contiguous spectrum free.

In these cases, technologies that improve the efficiency of spectrum utilisation can help operators gain access to the capacity/distance they need and, more generally, mitigate the impact of increasing capacity requirements leading to congestion issues. However, these effects will only be realised if the fixed links licensing regime facilitates take up of this equipment. Assuming it does, we would expect take up of more advanced equipment to be more significant in the long run, as operators need to swap out equipment anyway, and recognise that more sophisticated equipment could be better in terms of total cost of ownership.

XPIC configurations

In the first instance, operators can use both the horizontal and vertical polarisation on a link using cross-polarization interference cancelling (XPIC) technology. This allows users to double the capacity available to them without increasing the bandwidth used (and hence does not sterilise any additional spectrum for others). It does require equipment that supports

[20] Recommendation ITU-R F.636.5 (11/2019)

the configuration, so there may be an additional cost if the operator first uses a single polarisation before converting that to a dual polarisation link. However, licensees should be able to minimise any additional cost providing they can anticipate their additional future bandwidth needs.

XPIC technology has been available for a long time (approximately 10 years) and dual polarisation links are allowed (in fact they are encouraged) under ComReg's current fixed links licensing framework. Where a channel is used on a given link over both the vertical and horizontal polarisations, this is registered as two links with ComReg. However, ComReg does not charge a fee for use of the second polarisation, in order to incentivise efficient use of the spectrum. Dual polarisation is now mandatory for new applications for links on the same path, in the same band.

The licensing data shows that there is a significant number of links in Ireland operating on a dual polarisation, spread across bands and types of user. It would therefore appears that ComReg's approach to promoting use of XPIC arrangements has been effective in improving spectrum efficiency.

Carrier aggregation

Equipment that supports carrier aggregation allows users to utilise the combined bandwidth of two non-contiguous channels. The aggregated carriers may be in different parts of the same band or in different frequency bands altogether. This creates the option for increasing capacity over a link without requiring access to wider contiguous channels than currently licensed (or available given existing allocations).

In addition it allows for pairing spectrum in high frequency bands with traditional bands for the purpose of running high capacity links over longer distances than would typically be feasible with the high frequencies alone. The higher frequency band is used for providing capacity, with the lower band used for redundancy/reliability. Equipment to support multiband aggregation has only become commercially available in the last couple of years, so usage is not yet widespread, but could be expected to become more important in the future. At present the most common approach is to combine the 80 GHz band with the 18 GHz band, which allows for high capacity links of up to approximately 10km and may be useful in urban/suburban areas (e.g. for mobile backhaul in the cities). Where longer links are required (e.g. in rural areas) it is technically possible to combine frequencies in the 18 – 42 GHz range (for capacity) with lower bands such as 7 GHz (for reliability), but links

combining two of the traditional fixed links bands are not common and do not represent the expected typical use case.

An ECC draft report[21] on band carrier aggregation (BCA) suggests this technology has the following implications for licensing guidelines:

- a minimum link availability target should not apply to the highest band in a BCA system, which is typically operating at well beyond its stand-alone maximum link length;
- a minimum automatic transmit power control (ATPC) range may not be applicable to the higher band;
- high antenna class requirements should not be emphasised where dual band antennas are concerned; and
- in some cases, it may be appropriate not to enforce the minimum link length requirement for the lower band.

Currently, ComReg's guidelines encourage the use of technologies that improve spectrum efficiency and may grant exemptions from some (e.g. antenna class) requirements where there are no congestion issues. However, there are no specific provisions or exemptions from these rules for multi-band aggregation links.

Frequency re-use

Techniques for reducing/cancelling co-channel interference can lead to a reduction in the angle of separation required between links running over the same frequencies[22]. This improves frequency-re-use options and means that more links can run over the same frequencies within a given area, allowing for:

- increasing the number of links at a given site without increasing the bandwidth used; and/or
- increasing the channel dimensions (i.e. making larger channel widths available) for greater capacity without necessarily having to reduce the number of links.

Clearly this could be of use to operators who have links reaching out to multiple points from the same site, and so may be increasingly relevant if star network topologies become

[21] ECC, forthcoming, 'Band and Carrier/Channel Aggregation in fixed point to point systems'.

[22] For example, Ceragon's advanced frequency re-use technique https://www.ceragon.com/blog/blogs/backhaulforum/why-struggle-to-get-additional-wireless-backhaul-spectrum-when-you-can-reuse-the-spectrum-you-already-have/

more prevalent. Nevertheless, increasing the number of links that can be used over the same frequencies could have similar effects to dual polarisation in terms of effectively increasing the available bandwidth that can be used in a given area and improving spectrum utilisation.

Of course, individual links operating over the same frequencies in the same geographic area must be coordinated to avoid interference. The extent to which the interference cancellation technology can be used to introduce new links that would previously not have been possible therefore depends on whether these new links would interfere with other operators' existing links (which may be using equipment that does not support the narrower angle of separation). Although these techniques are positive and potentially very useful developments, ComReg's licensing regime and interference analysis cannot be based on the assumption of all operators using specific technology. However:

- other links operated by an applicant for a new link are ignored in the interference analysis, so operators would not blocked from getting licences for potentially conflicting links (and managing the interference themselves using this new technology) provided they do not interfere with other users; and
- if multiple users want to make use of new technology that allows for operating a set of links that would be prohibited by ComReg's interference analysis, they could simply licence the links under a single operator (as above) and manage the usage/interference between themselves.

Alternatively, it would seem that this interference cancellation technology might be naturally suited to a block licensing regime where licensees manage interference between links themselves and do not need to be concerned about what equipment other operators are using.

MIMO

MIMO (multiple-input and multiple-output) is a well established technology that increases the capacity that can be achieved over a given channel by using multiple transit and receive antennas at a each end of a link. Typically MIMO systems operate over a symmetric NxN configuration (i.e. N transmitters and N receivers), which offers up to N times the capacity of a single antenna system.

Advancements in MIMO technology, such as line-of-sight (LoS) MIMO, are allowing for more efficient high capacity links over

similar distances currently used for backhaul links. In its 2019 microwave outlook report, Ericsson suggests that P-P links supporting capacities of 100 Gbps or more will be commercially available within the next 5 – 8 years (depending on demand), but also that new spectrum efficient technologies (such as LoS MIMO) are going to be important for achieving mass deployment at these speeds.

The downside of MIMO is that operators naturally incur additional costs related to the extra equipment and tower space needed. However, these costs can be limited through use of MIMO in conjunction with other technology, such as XPIC, to reduce the number of antennas required e.g. deploying two dual-polarisation antennas at each end of a link would be the equivalent of a 4x4 MIMO system[23].

Adaptive modulation

Adaptive coding and modulation (ACM) promotes the efficient use of spectrum by matchning the coding and modulation to the conditions currently experienced on a fixed link. ComReg encourages the use of ACM, and requires applicants for a link using the technique to define a reference mode, which is then included in the licence details. The power limits on the licence still apply at all times, such that a link using ACM cannot adversely affect neighbouring links.

ATPC

ATPC involves users transmitting at lower power except when there is rain or fading events, which reduces intereference between links and therefore can ease congestion (remote transmit power control (RTPC) is another technique with a similar effect). As it is other links that benefit from a link transmitting at lower power, operators are only likely to adopt this technique if they operate a large number of links at similar frequencies in the same area (e.g. on a block licence), or if the licence conditions require them to.

One stakeholder noted that this technique has been available for a number of years but is not widely used, and another suggested it would be easier to impose on new links than existing ones. Use of ATPC is a condition for links deployed under the 26 GHz block licences, but the technique is not yet referred to in ComReg's guidelines for individual link licensing. We recommend that ComReg reviews these guidelines to encourage the use of ATPC, and other techniques mentioned in this spectrum as appropriate.

[23] Ericsson, 2019, 'Ericsson microwave outlook report 2019', https://www.ericsson.com/en/reports-and-papers/microwave-outlook/reports/2019

Interim conclusion

Therefore, based on the above, we believe there are a large range of technologies available to help use spectrum more efficiently, and support growing needs for bandwidth. In the long run (i.e. as they come to replace equipment anyway), we expect operators to have an incentive to adopt this equipment. Although major changes are likely unneccessary, ComReg should its ensure its guidelines allow the use of new, efficient technology.

3.5 Advanced technologies

As discussed above, point-to-multipoint links are currently not widely used in Ireland. However, during the stakeholder interviews there were suggestions that P-MP use, as well as mesh networks, could become prominent in the future with the development of new technology and changing network architecture. For example:

- There may be a use case for P-MP links and/or mesh networks in the unlicensed 60 GHz band (stakeholders have indicated that 60 GHz equipment is or soon will be available, Facebook's Terragraph system[24] will also use the band) and/or higher frequencies for localised high-capacity services (e.g. in business parks, with short links rather than fibre serving each premises);
- Next generation P-MP technology will allow for running more links on the same channel and also support 5G backhaul as mobile networks shift to a star topology configuration (with more links per site, in response to increased demand for bandwidth and cell densification). An ECC working report[25] suggests that the 28 GHz band is suitable for this, although the 32 – 42 GHz bands (or even higher) could be used in future; and
- There is already a demonstrable use case for advanced fixed wireless services using P-MP architecture in urban areas operating over the mmWave bands (discussed below).

[24] https://terragraph.com/

[25] ECC report, forthcoming, 'New microwave antennas based on active antennas for 5G backhaul above 27.5 GHz'

Spectrum scarcity and limited tower space may also lead to the use of new systems that can offer more efficient spectrum reuse and greater capacity than is available using traditional P-MP systems, such as:

- active form array antennas;
- beamforming;
- beam-nulling; and
- interference cancellation.

Advanced FWA technologies have already started to emerge, allowing operators to offer fixed wireless broadband services at much higher speeds. These typically use dense networks of links at higher frequencies and are aimed at competing directly with fixed networks in urban areas. Whilst these might not be an immediate prospect within Ireland, they are potential future use of certain fixed link bands that can provide necessary bandwidth with sufficient propagation.

A good example is provided by Starry,[26] a wireless ISP operating in the US. Starry uses a combination of active phased arrays, beam steering and MIMO technology over a P-MP network configuration to provide high speed wireless broadband in urban areas. The operator offers FWA at speeds comparable to 5G, but claims that its technology and network design means it is doing so in a much more cost-efficient manner.[27] The system is designed to operate over a range of frequencies in the millimeter bands. Starry is currently using a combination of light-licensed shared spectrum in the 37 – 39 GHz band and its recently acquired exclusively licensed spectrum in the 24 GHz band.

The millimeter bands, including the 26 GHz and 32 GHz (31.8 – 33.4 GHz) bands, would seem to be the 'sweet spot' for this type of service. They offer the large bandwidths needed to run high capacity links, but can still operate over distances that are long enough to be economical and not suffer from propagation issues. We note that Starry's network design allows for links in the millimeter bands that run for approximately 1.5 miles with only partial line of sight.

We are not currently aware of similar existing use cases in Ireland, and we recognise that these approaches are still new, but indications are that they could become more prevalent and

[26] See https://starry.com/technology

[27] https://wifinowglobal.com/news-and-blog/starrys-economics-could-blow-a-hole-in-5g-fwa-hopes/

we would not want to preclude such developments, as they could provide significant additional competition with fixed network services.

Interim conclusion

In summary, we believe that new technologies could lead to distinct use cases emerging in Ireland, and could see P-MP in the licensed fixed links bands becoming more important.

3.6 Specialist low latency links

Specialist low latency links are used to transmit information over long distances (over 100 km) quickly, for example between data centres for financial services. Covering such long distances in relatively few hops using microwave links means the information can be transmitted more quickly than with fibre, which would have to take a less direct route and may pass through format conversions and routing nodes.

Clearly link length, rather than capacity is the priority for these low latency links, therefore they are suited to relatively low frequency bands. This use case has only recently emerged in Ireland (a small number of links were installed in 2019), and uses bands from 6 – 13 GHz, although it may also be suited to even lower frequencies.

Ofcom, in its most recent fixed links review, noted that demand for fixed links from financial services had grown quickly in the preceding years, but had now stabilised. Links for this purpose in the UK commonly connected the South East of the country to mainland Europe.

Interim conclusion

In Summary, specialist low latency links may be an increasingly important use case in the lower frequency bands.

4 Potential uses for the fixed links bands

In this section we summarise the current and emerging use cases for fixed links that we have identified, discuss in further detail our understanding of the degree substitutability between the bands and the implications for efficient assignment, and set out our understanding and views on other (non fixed links) use cases that operate or may operate within the band.

We invite respondents to provide their views:

- on the identified use cases; and/or
- alert us to additional use cases that we have not identified.

4.1 Fixed links use cases

Based on our understanding set out in the sections above, we believe the set of key use cases for fixed links is as follows:

- narrowband telemetry and control;
- broadcast distribution;
- mobile backhaul;
- fixed wireless access;
- links within telecommunications core networks;
- advanced fixed wireless access; and
- specialist low latency links (e.g. for financial trading).

These uses vary greatly in bandwidth requirements and typical link length. In some cases, significant growth in demand for spectrum can be expected, but in others (e.g. broadcast distribution) little growth is likely.

We are also aware of a number of applications other than fixed links which nevertheless operate within the fixed links frequency bands, which we discuss further below. This focusses mostly on the potential introduction of ECS into the 1.4 GHz and 26 GHz bands, in light of the corresponding European Comission harmonisation decisions.

Fixed links use cases can be grouped by 'sweet-spots' within the available bands

Typically particular applications tend to be concentrated in certain fixed links bands that provide a suitable balance between link length/availability and bandwidth. However, most applications still have a degree of flexibility and are able to use a range of bands around some "sweet spot". This range of feasible alternative bands varies from use case to use case, and is often quite broad. Table 1 summarises our understanding of each use case (i.e. ignoring the fact that some bands, e.g. upper 8 GHz, are not widely used because of the limited available channel sizes). We explain our views on substitutability between the bands in detail below.

Table 1: Key bands for each use case

Use Case	Existing or new / potential use	Key bands	Comments
Telemetry and control	Existing	1.3/1.4 GHz, 6 – 8 GHz	Strong preference for high availability
Broadcasting	Existing	1.3/1.4 GHz, 6 – 11 GHz	Low bandwidth requirements
Mobile backhaul	Existing	11 – 42 GHz, 80 GHz	Includes use of block licences. 80 GHz predominantly for short, high capacity links in cities.
FWA	Existing	11 – 42 GHz, 80 GHz 5 GHz (licence exempt)	Band selected on a link by link basis according to specific link length/capacity requirements. Licence exempt 5 GHz band used mostly for P-MP broadband.
Links within core networks	Existing	6 – 23 GHz	Candidate for fibre replacement
Advanced FWA	Potential	23 – 42 GHz	Not yet established in Ireland

Specialist low latency links	New	6 – 13 GHz	Some recent usage in Ireland for financial trading

4.2 Efficiency and substitution

4.2.1 Chains of substitution

Whilst there will be a "sweet-spot" in terms of optimising the trade-off between capacity and propagation for any given use case, in practice there is typically a wide range of feasible frequencies and particular use cases are not limited to single bands. For example, a particular use case might be able to use spectrum in any of the bands between 18 GHz and 42 GHz, rather than being limited to the 28 GHz band only.

The range of feasible alternative frequencies will vary between applications. For example, one use case might need spectrum in the lower bands because of requirements for longer, reliable links; another use case might need the larger bandwidths available in the higher frequencies and may benefit in some cases from reduced propagation (e.g. to allow frequency reuse for short links in urban areas). Other use cases may need to strike a compromise between bandwidth and link length (for example, for high bandwidth FWA applications, where a need for reasonable link lengths may preclude moving to bands above 60 GHz).

Because of the wide variety of different use cases, we are very likely to have a situation in which each use case can use some range of bands, and very likely overlaps to some extent with other use cases that might be able to use a higher or lower range of bands. This means that bands form a chain of substitutes, in the sense that spectrum – at least hypothetically - be freed in one band by shuffling users either up or down using the range of flexibility available for each use case.

Where there is a chain of substitution, bands far apart in frequency – which might not even be seen as alternatives for any use case – can be indirectly substitutable as a result of shuffling along users using intermediate bands. An immediate consequence is that it may be impossible to create 'bright line'

cut-offs between fixed link bands, placing them into groups such that bands in one group are substitutes and those in different groups are not. Therefore, although some use cases favour lower bands, other higher bands and yet others middling bands, there are likely to be some use cases that are flexible across any boundary that we draw.

A further consequence of there being a chain of substitutes is that even if one band is scarce, in the sense of there being little current spare spectrum at a particular location, it may be possible – at least in the long-run once equipment is renewed – to shuffle users to different bands such that spectrum can be freed up. Therefore, it makes little sense to assess scarcity at the level of individual bands. This also means that the long-run opportunity cost of spectrum use may be low once we factor in the potential for shuffling around users over a sufficiently long time horizon.

4.2.2 Long-run vs short-run switching

The licencing regime should promote efficient use of the spectrum. In practice this means that where there are conflicts between different potential users, the user less able to switch to an alternative band, or to obtain connectivity in an alternative way (such as use of fibre), should be prioritised over those more able to switch. However, in considering switching possibilities, a long-run view should be taken where equipment can be replaced as it reaches the end of its economic life, rather than the short-run, where sunk investments in particular equipment may be committing and making changes of band costly.

Equipment costs

Equipment is typically retunable across either a whole fixed links band or a 'sub-band' (in which case the band is broken into two or three sub-bands, where the definition of sub-bands is specific to an equipment manufacturer). However, migrating to a different band would require the operator to replace hardware, with total costs of migration likely to be above EUR 5,000 per link (according to the RFIs), and the time taken would also be significant. This is considerably greater than any difference in fees between bands.

From our interviews, we found that equipment costs do not vary significantly between neighbouring bands, but the asset life tends to be long, and is not the constraint that leads equipment to be replaced (e.g. a link is upgraded because demand for

bandwidth has gone up, not because the equipment has stopped working).

Therefore, when considering the management of any congestion through scarcity charges for spectrum use, it is very important to take into account that existing users may be effectively immobile in the short run, but different bands may be highly substitutable in the long run (potentially through a chain of substitutes). Indeed, the long-run opportunity cost of spectrum may be low even for bands that are intensively used if, over a sufficiently long time horizon, users can move to other bands at modest cost. Consequently, the fee structure, information provided to applicants, and rules set out in the guidelines should be enough to encourage efficient use of the spectrum in the long run.

4.2.3 How operators choose bands

Preferences for availability or bandwidth

Operators, in response to the RFIs and through the stakeholder interviews, emphasised that link length policy is the most important factor in the selection of a band, and beyond that they simply select an appropriate size channel. This is consistent with the broad view above that, when new equipment is specified, there is usually some range of acceptable bands determined by the use case.

However, most links are licensed to operators who hold a large number of fixed links, and this trade-off is not the only factor when considering an operator's portfolio of links across the country, as we explain below.

First, some users concentrate their activities in a small number of bands to reduce the cost of holding spare equipment, but this is not possible for all use cases. Links in core networks will be planned over a long period of time, and within cities, high capacity links for mobile backhaul will mostly be at similar frequencies to each other. On the other hand, links for connectivity to isolated sites are installed on a customer by customer basis as demand arises, and the path length required varies accordingly. Therefore, some fixed wireless providers are less able to concentrate in a small set of bands. The substitutes in this case are the bands where sufficient spectrum is available to provide the speeds demanded by customers and links are long enough; for a given link this does not necessarily include every band that the licensee uses.

Second, for some users, it is especially important to be able to deploy links quickly. FWA providers with less difficulty meeting service level agreements (e.g. because they are in rural areas or they provide lower cost services) may use licence exempt spectrum to avoid fees and wait times, though the lack of interference protection is a barrier for most of these users. Block licences may also provide additional flexibility by providing a guarantee of spectrum availability.

Third, there are geographic constraints that can lead to localised scarcity and force use of bands than might be less than ideal for a particular application. This may occur if there are a limited number of high sites with good visibility to a point that needs to be connected with fixed links. In Dublin, there are a number of these key high sites to the South and South West of the city. The high demand in the area, coupled with the distances from these high sites to the city contribute to the current congestion. As a result:

- many users may be concentrated onto similar paths; and
- their preferred bands will then be determined by the length of those paths.

The 'area' constraints here are very specific and would not affect, for example, 80 GHz links within Dublin, if longer paths into the city were congested.

Fourth, there may be breaks in the chain of substitutes imposed by different treatment of bands within the licensing framework, such as differences in the channels available. For example, ComReg licenses 112 MHz channels in the 23 GHz and 28 GHz bands, but (for individual link licences) the widest channels available in the 26 GHz and 31 GHz bands are 28 MHz. A channel of a given bandwidth in each of these bands would be very close substitutes, except at the margin where, for instance, only the 23 GHz supported long enough links with good availability, but it a channel within the bands, rather than the bands per se, that are substitutes. Equipment may allow users to aggregate channels to avoid this issue, but it will come at an additional cost (discussed below).

Interim conclusion

Overall, it still seems link length policy is the most important factor, users will still never select a band that fails to meet link length requirements, but these points affect operators choice over similar bands, and explain why use cases cannot be concentrated into a single band.

4.3 Other uses within the fixed links bands

Some of the fixed links bands have been identified on a co-primary basis for other uses that coexist alongside fixed services. In this section we discuss these use cases and our current views on the potential implications for fixed links, with a focus on the international harmonisation of the 1.4 GHz, 26 GHz and 42 GHz bands for ECS.

4.3.1 5G in the 1.4 GHz, 26 GHz and/or 42 GHz bands

The 1.4 GHz band

WRC-15 identified the 1427-1452 MHz and 1492-1518 MHz frequency bands for International 5G use, and the 1427 – 1517 MHz band is now harmonised for electronic communication services in Europe. In April 2018 the European Commission[28] issued an amendment to the previous implementing decision on the harmonisation of the band for communications services in the Union (then covering only 1452 – 1492 MHz, 'the centre band'). The decision states that "*No later than 1 October 2018, Member States shall designate and make available, on a non-exclusive basis, the 1 427-1 452 MHz and the 1 492-1 517 MHz frequency bands, or a portion thereof, for terrestrial systems capable of providing wireless broadband electronic communications services*". These are the 'extension bands', and the Decision means the entire 1427 – 1517 MHz band is now harmonised for ECS.

Furthermore, the Decision stipulates that, where only a portion of the band is reserved for communications services administrations shall ensure that existing uses are maintained only where necessary, in a contiguous block between the sections of the band identified for mobile use, and with the aim of progressively making these bands entirely available for wireless broadband communications services. In effect existing

[28] European commission implementing decision (EU) 2018/661

uses, even where coexistence with 5G is not possible, may be allowed up to January 2023.

However, the European Commission noted that if no national demand for 5G has been identified for the bands by the deadline it may be extended. In line with the EC decision, the CEPT published its corrected decision on harmonised use of the bands for Mobile/fixed Communications Networks Supplemental Downlink (MFCN SDL) in March 2018[29].

The upper part of both the 1.3 GHz (1512 – 1517 MHz) and the 1.4 GHz (1427 – 1437 MHz) fixed links bands are within the range harmonised for ECS. At the moment, there are 57 live links in the 1.3 GHz band, and 31 live links in the 1.4 GHz band, held mostly by utilities and broadcasters. ComReg has considered awarding the band as part of the upcoming multiband spectrum award (MBSA2) but instead considers it appropriate to defer the release of this band. [30]

Although some countries have indicated in the BEREC RFI response that they have cleared the band for 5G use (i.e. France and Norway), others have yet to find sufficient demand for the band to warrant clearing it completely (i.e. Portugal and Slovakia). Austria and Switzerland have already awarded the band for mobile use.

The 26 GHz band

The 24.25 – 27.5 GHz band has been identified as the pioneer mmWave band for 5G in Europe, and harmonised for ECS in 2019 under Comission Implementing Decision (EU) 2019/784, which was amended by Comission implementing Decision (EU) 2020/590, stating that the band should be available for ECS on a non-exclusive basis by 30 June 2020. Furthermore, ECC Decision (18)06 on mobile/fixed communications networks (MFCN) in the band stipulates "*that CEPT administrations shall make available by the end of 2020 at least 1 GHz for MFCN in this band, subject to market demand*", with the expectation that it would mainly be used for supporting urban/suburban hotspots over a relatively

[29] ECC Decision (17)06, 'the harmonised use of the frequency bands 1427-1452 MHz and 1492-1518 MHz for Mobile/fixed Communications Networks Supplemental Downlink (MFCN SDL)'

[30] See Section 3.2.3 and Annex 6 ComReg Document 19/124 and in particular Paragraphs 3.37 and A.6.110.

small range[31], but does not preclude use of the band by other services. We note that ComReg has already considered the potential inclusion of the 26 GHz band as part of the upcoming MBSA2, and considers it appropriate to defer the release of this band until after the MBSA2[32]. In particular, when developing the Decision, the ECC recognised that the 26 GHz band is already used for fixed links in a number of countries and that some administrations will need flexibility over use of the band, depending on national circumstances and fixed links usage. The ECC also specifies that "*coexistence issues between fixed links and MFCN in the 26 GHz frequency band will be managed at national level or through the cross-border coordination framework*" and allows for a variety of approaches that could be taken regarding coexistence depending on national circumstances (e.g. the extent and density of fixed links usage in the band).

At present, in Ireland block licences in the 26 GHz band are assigned to the three MNOs (five 2×28 MHz blocks each) exclusively for point-to-point fixed links use until 2028. There are also a number of individually licensed links in the band, distributed across a limited number of users and with the majority held by the MNOs.

In addition to the fixed links licences:

- five 2×28 MHz blocks are currently set aside for FWALA; and
- Automotive Short-Range Radar and Industrial Probing may operate in parts of the band on a licence exempt basis but must not cause interference for other users.

We are aware that ComReg is undertaking a separate work item to assess the future licensing of the 26 GHz band and this workstream can be used to inform this..

The 42 GHz band

The 40.5 – 43.5 GHz band (the 42 GHz band) has been identified as a priority 5G band for CEPT.

[31] https://www.ecodocdb.dk/download/5e74d0b8-fbab/ECCDec1806.pdf

[32] See Section 3.2.3 of ComReg Document 19/124 and in particular Paragraphs 3.31 to 3.37.

In April 2020, and following the outcome of WRC-19, the EC issued a mandate to CEPT to harmonise the 42 GHz band[33], and and work item[34] has been launched to "*…develop least restrictive harmonised technical conditions suitable for next-generation (5G) terrestrial wireless systems…"* in the band. A draft report for public consultation is expected in March 2021, with the final report planned for July 2021.

4.3.2 Fixed Satellites Services

Both coordinated and uncoordinated Fixed Satellite Services (FSS) operate in, or adjacent to, a number of the bands subject to this review[35]. Where FSS is allocated on a protected co-primary basis, coexistence with fixed links is straightforward, and requires fixed links transmitters to be at a sufficient distance away from Earth Stations (most cases implemented through band segmentations/guard bands) or in some cases to implement power reduction mechanisms[36](e.g. 31-31.3 GHz band). Whilst when FSS services are assigned to the band on an unprotected basis, administrations are required to limit interference to FSS only where reasonable (e.g. 37.5-39.5 GHz). Therefore, provided that there are appropriate checks for interference with these stations, we do not believe that it affects ComReg assigning any of the bands under review to fixed services.

Fixed links to the south of satellite Earth stations could interfere cause interference (i.e. a link at a certain angle and elevation relative to an Earth station, given that satellites are clustered around the Equator). However, Earth stations are typically not in urban areas, and ComReg already works with applicants to find a suitable location for these stations, for example, a fixed link on Three Rock, to the south of Dublin, would interfere with an Earth station in Dublin City Centre using the same band, but this would of course be an unlikely site for that station. Therefore we do not expect coexistence between fixed links and fixed satellite services to be an issue, provided ComReg continues to follow

[33] https://www.cept.org/Documents/ecc-pt1/59102/ecc-pt1-20-078_ec-mandate-to-cept-on-mm-wave-bands

[34] http://eccwp.cept.org/WI_Detail.aspx?wiid=757

[35] See ComReg 00/64 R3 for a list.

[36] ECC Decision (05)01, 'The use of the band 27.5-29.5 GHz by the Fixed Service and uncoordinated Earth stations of the Fixed-Satellite Service (Earth-to-space)'

international harmonisation measures for the bands which also promote this coexistence.

4.3.3 Multimedia Wireless Systems

The 11 GHz (10.7-12.5 GHz) and 42 GHz bands (40.5-42.5 GHz) are also designated on a primary basis to the use of Multimedia Wireless Systems (MWS)[37] (i.e. Broadcasting satellite services). To avoid interference between the various services in the 11 GHz band, Fixed services cannot be deployed in the higher portion of the band (11.7-12.5 GHz). Furthermore, the ECC offers recommendations and guidelines for accommodating both the Fixed services and MWS in the 42 GHz band[38]. These measures should be sufficient to ensure coexistence between the two services in the bands.

4.3.4 Military applications

As part of the NATO Frequency agreement parts of the frequency band 7125-8500 MHz is used for Military satellite communications and fixed services links, as such in many CEPT countries the whole range is not available for fixed services applications[39]. However, this does not seem to be the case for Ireland. Similarly, the ECA has identified the 71-74 GHz and 81-84 GHz as harmonized for military bands for defence systems but can be shared between civil and military on a country by country basis.

SRDs may also use some of these bands[40], but the range and limited interference potential of this equipment, means coexistence with fixed links should be straightforward.

[37] ERC/DEC/(00)08 for the 11 GHz band and ERC/DEC/(99)15 for the 42 GHz band

[38] ECC Recommendation (01)04, 'Recommended guidelines for the accommodation and assignment of multimedia wireless systems (MWS) and point-to-point (P-P) fixed wireless systems in the frequency band 40.5 - 43.5 GHz'

[39] ECC Recommendation (02)06, 'CHANNEL ARRANGEMENTS FOR DIGITAL FIXED SERVICE SYSTEM OPERATING IN THE FREQUENCY RANGE 7125-8500 MHz'

[40] CEPT/ECC, ERC/REC 70-03, 'Relating to Short Range Devices (SRD), 12 June 2020

5 Issues and recommendations for specific bands

This section sets out our preliminary views on the existing fixed links bands. Except where the band has been harmonised for ECS or MFCN, all of these bands are assigned to fixed links (possibly on a co-primary basis with other services e.g. satellites), and so will likely continue to be fixed links bands in the future, in line with ComReg's normal approach of following international harmonisation measures. However, there are issues specific to subsets of the bands that either lead us to suggest minor changes to the licensing framework, or on which we would like further views from stakeholders. The table below summarises the key issues and our provisional recommendations for each band.

Table 2: Summary of issues for each band

Band (GHz)	Comments	Provisional recommendation
1.3	Harmonised for ECS/MFCN	Seek views on when the band will be required for MFCN Give notice that fixed links may need to be cleared
1.4	Harmonised for ECS/MFCN	Seek views on when the band will be required for MFCN Give notice that fixed links may need to be cleared
2	Usage is currently low, but may increase if 1.3/1.4 GHz bands are closed	No change
L6		No change
U6		No change
L7	Low usage	No change

U7		No change
L8		No change
U8	Low usage Maximum channel size is 14 MHz	No change
11	Dual polarisation links are very common	No change
13	Closed to applications in congested area	Consider reopening, subject to information policy changes
15	Closed to applications in congested area	Consider reopening, subject to information policy changes Offer 112 MHz channels in line with ITU recommendation
18	Congested May be combined with 80 GHz for multi-band links	No change, subject to review of congestion charging
23	Congested	No change, subject to review of congestion charging
26	Harmonised for ECS/MFCN Sufficient free spectrum in the band to meet immediate requirement	No change to existing block licences Await separate review of 26 GHz band
28		No change
31	Unused	No change

	Maximum channel size is 28 MHz	
38		No change
42	Considered for ECS/MFCN	Await ECC Decision on harmonisation
80	Increasingly important for short, high capacity links	Seek views on potential for block licensing

5.1 Licensed bands

5.1.1 1.3 GHz & 1.4 GHz

We recommend that ComReg continues with its intentions set out in the MBSA2 process and in its spectrum strategy statement where it noted that it would "*monitor developments in the 1.4 GHz [B]and for MFCN and consider the current and future use of the band in Ireland.*"[41]

As the band is likely to be used for ECS in future, sufficient notice should be provided to current fixed links users regarding ComReg's plans for repurposing the band. Current users should be aware that, while they will not immediately be required to migrate out of the band, it may be removed from the fixed links framework at some point in the future.

There are currently 88 P-P links across the 1.3 GHz and 1.4 GHz bands, but we expect that most of these could be migrated to other bands that support long links with high availabiliy, although this would require the purchase of new equipment. In particular, Figure 41 in Annex C suggests that most link lengths on 1.3 GHz and 1.4 GHz links could be supported in other bands (i.e. 2 GHz, 6 GHz) where a significant amount of spectrum is available (2×85 MHz in the 2 GHz band compared to 2×15 MHz across the 1.3 GHz and 1.4 GHz bands), and there is currently no congestion. However, we recognise that there may be a very

[41] Document 18/118, "Radio Spectrum Management Strategy Statement 2019 to 2021", published 20 December 2018

small number of links where repeater sites are needed to replace very long distance links with higher frequency ones.

We would invite stakeholder views on:

- when the 1.4 GHz might be required if it is not included as part of ComReg's proposed multi-band spectrum award[42]; and
- how existing users would deal with transition from the band (assuming they would be given a suitably long notice period in which to do so), what alternative bands they would use, and whether any changes are needed for alternative bands (e.g. 1.75 MHz channels in the 2 GHz band).

5.1.2 2 GHz to 8 GHz

Sub-10 GHz spectrum is important for some use cases, but there is little risk of congestion

In line with stakeholder's responses, the lower frequency fixed links bands appear to be used predominantly where operators require long, high reliability links and bandwidth is not a key issue (e.g. telemetry and control applications). There does not appear to be any particular issues of congestion at the moment or potential problems in the future, in particular as many operators are moving towards a network of shorter, higher capacity links. However, we understand that there may be some scope for using these bands as part of a multi-band setup for providing the redundancy layer on longer (20-30km) rural links, though the relevant equipment is not currently available to operators.

Therefore, we do not believe ComReg needs to make any changes to the fixed links framework that are specific to these bands.

We note that the lower 7 GHz and upper 8 GHz bands contain considerably fewer links than the other 6 – 8 GHz bands. In the case of the upper 8 GHz band, this may be a result of the smaller channel sizes available.

[42]In its current consultation process, ComReg is of the preliminary view that, while the 1.4 GHz Centre Band is available for use and a device ecosystem is beginning to develop, effective management of the radio frequency spectrum in order to promote competition would be better facilitated by not including the 1.4 GHz Centre Band in the Proposed Award

While we do not see any need to make changes, we invite views on the usefulness of the 2 GHz to 8 GHz bands.

5.1.3 11 GHz to 23 GHz

The 11 GHz to 23 GHz bands are widely used for most of the main use cases. In Dublin, the 13 GHz to 23 GHz bands are congested, largely due to the compatibility with the link lengths required for reaching the city centre from strategic high sites on the outskirts. A number of links in these bands may be replaced with fibre, but we cannot rely on this to solve congestion issues, for example if users retain the fixed links as backup to fibre connections.

Reorganisation of the band is unrealistic, but applications for wider channels could be considered

Any forced reorganisation of the band (i.e. shifting users either within the band or to alternative bands) would be highly complex because of the extensive use of the band. Therefore, we do not recommend changes to the licensing regime that would require this (e.g. introducing block licences in the band).

Operators are interested in wider channels being made available in the 11 GHz, 13 GHz, and 15 GHz bands, and some may vacate the band if these are not available. If ComReg revises its band plans following new CEPT/ITU recommendations (e.g. to incorporate the new ITU recommendation to include 112 MHz channels in the 15 GHz band), we see no reason that wider channels in these bands should not be included. In practice, it may not be possible to accept many applications for wider channels in the band, as there is limited bandwidth available, particularly in Dublin. In any event, users have other options available to them, including alternative bands, fibre and carrier aggregation technology.

Space may have opened up in the 13 GHz and 15 GHz bands

Despite these bands being important to many users, we have seen a fall in the number of live 13 GHz and 15 GHz links following ComReg's closure of the band to new applications in Dublin. Presumably it is possible to accept more applications in the congested area than was possible at the time of these bands' closure, as the channels on cancelled licences are now vacant. We suggest that this should be thought of as a simple information policy, which in this case is too blunt and risks leaving spectrum inefficiently unused. Therefore, ComReg should consider reopening the 13 GHz and 15 GHz bands in the congested area as appropriate. Below, we explain potential

amendments to the information policy with regards to measuring congestion; it is likely best to wait for any amendments to the information policy to be implemented before potentially reopening the bands.

5.1.4 26 GHz

Block licences are currently assigned for P-P links in the 26 GHz band until 2028 (five 2×28 MHz blocks assigned to each of the three MNOs). In addition to these, there are some individually licensed links distributed across a limited number of users, with the majority held by the block license holders.

However, the 24.25 – 27.5 GHz band has been identified as the pioneer mmWave band for 5G in Europe, and in 2018 was harmonised for mobile/fixed communications networks with a requirement to make at least 1 GHz in the band available for 5G by the end of 2020. There is therefore a potential (future) conflict in demand for use of the band between MFCN and fixed links.

ComReg is assessing this situation and options for the future licensing framework for the 26 GHz band in a separate work item, and recommendations in that regard are therefore beyond the scope of this project.

5.1.5 28 GHz and 38 GHz

The number of links in the 28 GHz band has been increasing in recent years, while the number of links in the 38 GHz band has been falling, albeit from a much higher level. However, they may be in demand in future, because:

- the 112 MHz channels available may be useful in meeting growing bandwidth requirements; and
- the propagation characteristics of the 80 GHz band or above are not suitable for some use cases.

Stakeholders identified the 28 GHz and 38 GHz bands as potential replacements for the current block licences in the event that the 26 GHz band needs to be cleared for 5G in the future, noting that these bands may not be suitable in any case, because there are a number of existing individual links in the 28 GHz and 38 GHz bands so it might not be easy to reconfigure the band/licensing regime.

We do not believe that ComReg needs to make any changes to the fixed links regime specifically for these bands.

5.1.6 31 GHz

The 31 GHz band (31.0 – 31.3 GHz paired with 31.5 – 31.8 GHz) was made available by ComReg in 2012 for individually licensed P-P fixed links, in response to demand from stakeholders.

However, there has since been no use of the band at all, and the information received from stakeholders during the interviews and in the RFI responses does not provide any indication of demand for the band in the near future, because what is currently available (i.e. a limited number of 28 MHz channels) is apparently not optimal for use of frequencies in this range, and operators prefer higher capacity links in neighbouring bands.

We are generally of the view that there is little advantage in closing any of the fixed links bands without a clear benefit, and do not currently recommend doing so for the 31 GHz band.

However, to inform a final recommendation we would appreciate feedback from stakeholders on:

- why the 31 GHz band is not utilised;
- expectations over usefulness of and demand for the band for fixed links applications in the future; and
- whether there are alternative uses of the band that could represent a more efficient use of the spectrum.

5.1.7 42 GHz

As highlighted in Section 4.3.1, the 42 GHz band has been identified as a priority band for 5G, and development of harmonised technical conditions in the band is the subject of an ongoing CEPT work stream[43].

Depending on the terms of the final harmonisation Decision there may be consequences for fixed links use within the band. However, until further details are provided, there would not seem to be any need for changes to the fixed links regime

[43] http://eccwp.cept.org/WI_Detail.aspx?wiid=740

within the band, in particular as we would not expect the 42 GHz band to be required for 5G before the pioneer 26 GHz band. Having said that, stakeholders should be aware of the developments and make their network planning decisions accordingly.

5.1.8 80 GHz

As per the RFI's and interview responses, the 80 GHz band is very important for providing high capacity links. The concentration of 80 GHz links in high density networks in urban areas makes the band a candidate for block licensing (we discuss the conditions under which block licensing is suitable in general in the following section).

The limited use of the band in rural areas suggests that sub-national block licensing may well prove a suitable approach. It may be feasible/desirable, for example, to introduce a scheme where block licences are allocated in urban areas (where we might otherwise run into the difficulties regarding interference management), but individual link licences are used elsewhere.

However, the band is currently used heavily with demand increasing significantly over the last few years and therefore there is a concern that existing use could make any sort of reorganisation so complex that adjusting the licensing regime to introduce block licences is not economically viable. There are currently around 1,800 links in the 80 GHz band, over 1,000 of which are in Dublin. It may therefore be challenging to introduce block licensing in Dublin (which would seem to be the area that would most benefit from the change) given the large number of links that would potentially be affected. In other cities there are relatively few link licences (the largest number being ~75 links in Cork) so we might feasibly consider block licensing in those areas, albeit that might appear somewhat incongruent with the Dublin situation.

We would like to invite stakeholders on views with regards to:

- the potential benefits of block licensing in the 80 GHz band; and
- whether transition issues mean it is too late to introduce block licences in the band.

5.2 Licence exempt bands

5.2.1 5 GHz, 17 GHz, and 24 GHz

There is slightly more spectrum available in the 5 GHz band, compared to the 17 GHz and 24 GHz bands, and according to the RFIs most licence exempt links currently operate in the 5 GHz band. All of the operators in these bands are relatively able to tolerate the risk of interference (e.g. because they operate exclusively in rural areas). For some users of these three bands, licence fees were relatively important, compared to other fixed links users who choose bands based on link length requirements and exclusively use the licensed bands. As a result, some users were able to move up from 5 GHz to the 17 GHz and 24 GHz bands, which they have done primarily to avoid interference, which is less likely as there are fewer links in the higher two bands, rather than to access greater bandwidth.

The 17 GHz band was removed from ERC/REC 70-03 for short range devices (SRDs) in 2012, following WRC-12 and the ITU recommendation that the wider 15.4 – 17.3 GHz band should be used for radar applications.[44] However, CEPT report 44 acknowledges that the 17 GHz band is used in some CEPT countries for licence exempt fixed links applications, and therefore allows for the possibility that individual countries can continue to make the band available on a licence exempt basis.[45]

ComReg is right to follow international harmonisation measures when opening new bands to fixed links, but there is no reason to close bands that are already open and in use, unless there they are precluding an alternative use which is more valuable or which the band is harmonised for. This is not the case for the 17 GHz band.

As the bands are important to some users, we do not recommend that ComReg makes any changes to the 5 GHz, 17 GHz or 24 GHz bands, because:

[44] Recommendation ITU-R M.1730 (https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.1730-1-200910-I!!PDF-E.pdf)

[45] CEPT, CEPT report 44, 'In response to the EC Permanent Mandate on the "Annual update of the technical annex of the Commission Decision on the technical harmonisation of radio spectrum for use by short range devices"', pp 33-34, 8 March 2013.

- there are no harmonisation measures that require the bands to be used for other purposes;
- no stakeholders suggested any particular changes to the bands (e.g. they do not need additional interference protection); and
- closing any of these bands would force users into licenced bands (e.g. 6 GHz, 7 GHz, 8 GHz), which would neither be in the interst of the current licence exempt users (who would have to buy new equipment and pay licence fees), nor the operators in those bands, who would be more likely to face congestion issues.

5.2.2 60 GHz

The 60 GHz band has not enjoyed extensive use to date. However, we anticipate that this band could become important in the future, for example for localised dense-cell applications that can cope without formal interference protection.

As a general principle, we would recommend making as much spectrum available as possible, where doing so would not preclude its use by more valuable use cases in the future. Having more spectrum available and as lightly licensed as possible will encourage users without a need for stringent interference protection to use the band (e.g. so they can deploy new links quickly). Otherwise, these operators would have to use the licensed bands, which would leave less spectrum available for other users.

To that end, we note that ComReg's latest list of bands available for licence exempt use of SRDs[46] makes the 57 – 71 GHz band available for use by outdoor devices, subject to certain power limits. This was opened in accordance with ComReg's general approach of following international harmonisation measures for fixed links bands, and as a result, there is now a large amount of licence exempt available for short range, high capacity use cases.

With regards to the 66 – 71 GHz portion of the band this has been identified as a priority band for 5G use[47]. We note that 5G use of the band may not be on an exclusive basis, and there

[46] ComReg 02/71 R12, Table 3

[47] RSPG18-005 – RSPG strategic roadmap towards 5G for Europe, RSPG second opinion on 5G networks – 30 January 2018.

would be fewer interference issues than with lower frequency bands, therefore there may still be scope to use it for fixed links. Nevertheless, users should be aware that the band may be harmonised for ECS/MFCN in future.

We would also like to receive views from respondents on:

- likely uses of the band (noting that the stakeholder interviews may not have picked up demand from some new/innovative users); and
- whether there are likely to be issues with 5G coexistence in the 66 – 71 GHz portion of the band in future.

5.3 Rationalisation and new bands

5.3.1 Rationalisation of current bands

The large number of bands currently available for fixed links licences (some of which are not heavily used) leads to the question of whether some 'rationalisation' could take place. This could involve, for example:

- closing off bands where there is currently limited (or no) use; or
- consolidating users of multiple substitutable bands into a subset of those (and then closing the cleared band(s)).

In general we do not see any particular rationale for clearing and/or closing off any of the fixed links bands unless there is a clear benefit from doing so, in particular in the current environment of growing bandwidth requirements and where some of the existing bands (i.e. 1.3 GHz, 1.4 GHz, 26 GHz and 42 GHz) will potentially be repurposed (in whole or partially) for 5G at some point in the future.

As discussed above, the range of bands available conforms with international harmonisation/recommendations, is in line with the approach in other major European countries, and is generally necessary to support the wide range of use cases and link requirements.

Clearing out and/or closing bands to fixed links when there is no better alternative use of the spectrum potentially risks leaving spectrum inefficiently unused. Even if a band is not used

heavily at present, this does not mean that it is not important for the users (if any) that are there, and it does not mean that there will not be demand for the band in the future as services and technologies evolve. Absent any alternative (and more valuable) use case, there does not seem to be any particular downside to keeping the band open for fixed links, whereas closing it could inefficiently withhold the band when there is demand for it.

Where (substitutable) bands are more heavily used, consolidating users into a smaller number of bands is also likely to be complex and time consuming, and moreover could risk creating issues of congestion (even if very localised) where users are packed into a smaller quantum of spectrum that is insufficient to meet increasing capacity requirements. Again, this would be appear to be very little or no benefit with no significant cost to keeping all of the bands in question available.

In Ireland, we identify seven bands where we believe current usage could be considered limited (<100 links). These are the 1.3 GHz, 1.4 GHz, 2 GHz, L7 GHz, U8 GHz, 31 GHz and 42 GHz bands (where the 31 GHz band is the only one currently with no users, although the L7 GHz and U8 GHz bands each have fewer than 10 links).

Of these bands, the 1.3 GHz, 1.4 GHz and 42 GHz bands have all been identified as important bands for 5G and may therefore be repurposed at some point in the future in any case. Having said that, and not least since there would not be any alternative use to fixed links before 5G is introduced, we do not believe there is any reason to close these bands earlier than necessary. In particular, with regard to the 42 GHz band this is likely to still be some way off and there seems to be no immediate rush to close the band in preparation when it could be positively utilised in the meantime. Note that the same argument applies to the 26 GHz band. Nevertheless, it is important that, in each case, the current users are provided with sufficient warning of developments in ComReg's plans regarding the band.

With respect to the other bands, we have not identified any significant alternative use cases that would warrant closing them to fixed links (although we would appreciate feedback from stakeholders if they believe our understanding in this regard is incorrect). In addition to the general arguments for not closing theses bands (set out above), we also observe that:

- the 2 GHz band is the closest band to the 1.3 GHz and 1.4 GHz bands, and the only other fixed links

band below 6 GHz. Therefore, although there is only one user of the band at present, it may become important for operators currently using the 1.3 GHz and 1.4 GHZ bands if/when they are repurposed for 5G; and

- similarly, although not used to date, the 31 GHz could provide an alternative option for operators using individual link licences in the 26 GHz band should (some or all of) that band need to be cleared for 5G.

Overall, we do not see any good reason to rationalise the current set of fixed links bands beyond what may be required to comply with ECC requirements for the introduction of 5G.

However, we would invite stakeholders to provide any alternative views on rationalising bands.

5.3.2 Opening new bands

Increasing demand for bandwidth and the fact that some bands (particularly 26 GHz) are likely to be cleared of fixed links at some point means there are grounds for adding new bands to the fixed links framework, if/when the bands are identified for fixed links use internationally.

As part of the review, ComReg is considering opening up frequencies in the 130 – 134 GHz, 141 – 148.5 GHz, 151.5 – 164 GHz and 167 – 174 GHz bands (collectively referred to as the D-band) for fixed links.

During the course of the interviews, other bands not currently used for fixed links were also mentioned by several interviewees. In particular, the W-band (92 – 114.25 GHz) and the 32 GHz band were suggested as bands that could (at least at some point) be made available for fixed links. We explain in the following section that greenfield bands where interference analysis is difficult are likely to be strong candidates for block licensing; this includes all of the bands discussed in this section.

32 GHz

In the event that the 26 GHz band is cleared of fixed links at some point in the future, the 31 GHz and 32 GHz (31.8 – 33.4 GHz) bands have been raised as suitable alternatives. As discussed above, the 31 GHz band is open but unused as there

are only nine 28 MHz channels available with satellite services[48] both immediately before and in the gap between the paired channels (i.e. 31.3 – 31.5 GHz), therefore it is unlikely to be a suitable replacement for the 26 GHz block licences. There is considerably more spectrum available in the 32 GHz band, which is no longer considered a priority band for 5G[49], but is allocated to fixed services on a primary basis.[50] Radio navigation services are allocated to the 32 GHz band on a worldwide basis, and ITU-R studies have suggested they are incompatible with IMT use of the band. Therefore, CEPT is of the view that the 32 GHz band will not be used for IMT/5G, and suggests it could instead be used to accommodate fixed links that are migrated from the 26 GHz band[51].

Block licences have been assigned in the band elsewhere in Europe, most recently in an auction for multiple fixed links bands in Norway, but also in the UK.

Although, It is currently unclear how much of the 26 GHz band will be needed for 5G if we were to identify the 32 GHz band as a replacement for block licence in the 26 GHz, this would not need to be made available until circa 2028 when the block licences actually expire.

However, there may be demand for the 32 GHz band from other use cases before 2028. The fixed links use cases highlighted by the stakeholders during the interviews and in response to the RFIs may not form a fully representative view, and there may be additional applications beyond what the MNOs would be looking to do (e.g. advanced FWA).

In this case there does not seem to be any reason for delaying access to the spectrum and if there is sufficient demand expressed, ComReg may consider making the band available sooner. MNO's would likely also prefer an earlier award date to have sufficient notice for migrating all their existing links into the band.

[48] ECC, 2010, 'ECC Decision of 12 November 2010 on compatibility between the fixed satellite service in the 30-31 GHz band and the Earth exploration satellite service (passive) in the 31.3-31.5 GHz band', ECC/DEC/(10)02.

[49] As a result of resolution 238 of WRC-15, the 31.8–33.4 band was being considered as a potential 5G band. However, following the WRC-19, the CEPT did not identify it as a 5G priority band at this stage. https://cept.org/ecc/topics/spectrum-for-wireless-broadband-5g#/roadmap

[50] Rec. ITU-R F.1571, p. 1

[51] CEPT/ECC Doc. CPG(19)143 ANNEX IV-13, 'CEPT Brief on WRC-19 Agenda Item 1.13', 30 August 2019.

We would like to invite views from stakeholders on whether:

- block licences in the 32 GHz band would be a suitable long term (2028) replacement for block licences in the 26 GHz; and
- when the band would be required.

W-band

There is over 15 GHz of spectrum available between 92 GHz and 114.25 GHz in the W-band. This is immediately above the E-band (80 GHz), and is viewed as an extension to that band should it become congested. The frequencies allocated to fixed services as a primary service in the band are[52]:

- 92 – 94 GHz;
- 94.1 – 100 GHz;
- 102 – 109.5 GHz; and
- 111.8 – 114.25 GHz.

In the stakeholder interviews, equipment manufacturers tended to be more convinced of the usefulness of both of the W-band and the D-band than operators. Equipment for these bands is still in development and technical specifications (e.g. ETSI standards) are not yet available, although they are expected by the end of this year.

The band is not yet harmonised, but ECC Recommendation (18)02[53] provides example channel plans for the band, and ECC Report 282 discuses P-P applications in the band, noting that:

- the main use case is likely to be high capacity mobile backhaul/fronthaul between small cells in urban areas, though there will also be FWA applications;
- the US Federal Communications Commission (FCC) has reported on fixed services above 95 GHz;
- new technical approaches are required to meet future speeds of up to 10 Gbps; and
- licence exempt use of the band may not be appropriate (e.g. because light licensing/licence

[52] ECC Report 282, 'Point-to-Point Radio Links in the Frequency Ranges 92 – 114.25 GHz and 130 – 174.8 GHz', 14 September 2018

[53] ECC/REC/(18)02, 'Radio frequency channel/block arrangements for Fixed Service systems operating in the bands 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz and 111.8-114.25 GHz', 14 September 2018

exempt use of the E-band in some jurisdictions was ultimately replaced with link-by-link planning).

Interference analysis may be difficult for dense clusters of short links in the band, so they would appear to be strong candidates for some form of block licensing. Equally, it may not be suitable for national block licences, or even traditional regional block licences as clusters of links are confined to much smaller areas.

We do not recommend making the band available until there is a clear need for the spectrum and there is equipment available to be used in the band. Nevertheless, ComReg should consider setting out a plan for making the band available at some point.

We would appreciate views from stakeholders regarding:

- under what conditions they would be interested in the band; and
- what they believe a suitable licensing regime for the band would look like (with the particular regard to the definition of block licences).

D-band

The D-band includes all four of the candidate bands that identified in the RSMSS (130 – 134 GHz, 141 – 148.5 GHz, 151.5 – 164 GHz and 167 – 174 GHz). ECC Recommendation (18)01[54] notes that there is interest in the band due to the large amount of bandwidth available, and provides example channel arrangements, noting that traditional link by link planning may be difficult in the band.

It is also discussed in ECC report 282, and many of the same points discussed in relation to the W-band apply, in particular that there is currently no available equipment in the band and that future use cases will deploy dense clusters or short, very high capacity links.

However, stakeholders have explained that the D-band has potential for use of substantially different technology to the lower bands, which will support very high capacities, whereas the W-band would have a limited effect in terms of making new use cases possible, as it would be an extension to the E-band.

[54] ECC/REC/(18)01, 'Radio frequency channel/block arrangements for Fixed Service systems operating in the bands 130-134 GHz, 141-148.5 GHz, 151.5-164 GHz and 167-174.8 GHz', 27 April 2018

For example, flexible FDD (fFDD) technology[55], where the transmit and receive channels can be an arbitrary distance apart, may be possible in the D-band.

Again we do not recommend releasing the D-band until equipment for the band is available, but we do expect it to be useful in the future given the bandwidth growth we have seen. It would likely be a candidate for micro block licences, as it is a greenfield band where users will likely want to deploy large clusters of links.

We would like to invite views from stakeholders on the:

- likely use of the candidate bands; and
- suitable licencing framework (with particular regards to the structure of block licences).

5.3.3 Road map for candidate bands and other bands

As set out in relation to closing bands that are to be used for 5G, ComReg should give as much clarity and notice as possible when changing the bands available for fixed links. This allows users to migrate when equipment cycles make it suitable to do so, and avoids spectrum being left unused for a time.

Equally, the bands that could be opened are likely to play a role in meeting demand for bandwidth on fixed links in the future, but they should not be released immediately.

ComReg should set out a roadmap for if/when further spectrum (e.g. W-band, D-band, 32 GHz) would likely become available. We recognise that ComReg does not have sufficient information to be able to set out a precise timetable at this stage, but it should engage further with stakeholders at some point on when a suitable time for allocating the bands (likely as block licences) might be. Equipment availability and the expiry of 26 GHz block licences will be important factors for consideration in the roadmap for candidate bands.

[55] Annex 2 of ECC Report 282 discusses the impact of a reflection study on flexible reduced duplexing in relation to fFDD.

6 General licensing options

ComReg currently provides individual link licences, national block licences (in the 26 GHz band), and licence exempt spectrum. In this section we explain our views on the conditions under which each licensing option is appropriate and the parameters that can be varied on each option (e.g. geographic scope of block licences, registration requirements for otherwise licence exempt spectrum). Annex A provides further details of ComReg's current licensing framework.

6.1 Individual link licences

Individual link licences permit the holder to operate a single fixed link between two points, using a particular channel, for one year (unless it is a temporary licence), subject to licence conditions.

6.1.1 Technical guidelines

The fixed links guidelines set the rules that applicants for individual links licences will have to comply with, both at the application stage and as the conditions on the licence. The guidelines include:

- guidance that encourages useful techniques or behaviour, such encouraging the use of particular technologies and network planning; and
- explicit restrictions that prevent obviously inefficient use of the bands, for example minimum path length requirements.

Equipment

Guidelines may need to be reviewed regularly in order to keep pace with equipment development, for instance multiband links may could lead to a more efficient use of spectrum, but may not meet availability, antenna standards, or path length requirements if assessed in the same way as a basic link. Accommodating this technology could involve, if/where deemed necessary, expanding the list of techniques explicitly mentioned in the guidelines.

However, there is no reason that facilitating the use of spectrum efficient equipment should be overly burdensome for ComReg. Provided that the guidelines do not specifically prohibit certain

behaviour, it should be possible to deploy new equipment as soon as it is available. For example, links licensed to the same user are excluded from ComReg's interference analysis, which allows operators to use active interference cancellation techniques, as discussed above.

Channel spacing

We see little downside to making larger channels available (e.g. to offer the 112 MHz channels stakeholders have expressed an interest in), where feasible and in line with the international recommendations. We understand that operators may simply acquire licences for two adjacent channels and use them as if they were one (e.g. two 56 MHz channels could be utilised as if they were a single 112 MHz channel). ComReg may therefore consider increasing its use of the option to form larger channels by merging smaller ones, in bands where it does not already do so and where there is likely to be demand for the larger channels.

In other bands, where ComReg already allocates the largest channel widths allowed by the relevant CEPT or ITU recommendations (these generally align, but ComReg uses ITU recommendations when CEPT/ECC ones are not available), ComReg's general policy of following international guidance means that increasing the maximum channel widths would require deviating from current recommendations (or at least moving ahead of likely standardisation developments). In that regard, we note that in November 2019 the ITU updated its recommendations on channel arrangements in the 15 GHz bands to include 112 MHz channels.

We also understand that the ECC is currently considering the doubling of the maximum channel widths for the 11 GHz, 18 GHz, 28 GHz, 23 GHz, 32 GHz and 38 GHz bands. An initial report was published in October 2020 and appears to suggest that wider channels in those bands would be feasible.[56] Following the findings of that report and any resulting adjustments to the ECC/ITU recommendations, ComReg may consider amending the range of channel sizes it offers accordingly in the relevant band(s). The ECC report does not, however, include consideration of the 13 GHz band or the 15 GHz band, because it would only be possible to make a handful

[56] https://docdb.cept.org/download/b7f53395-a40b/ECC%20Report%20319.pdf

of 112 MHz channels available in each case, but ComReg uses the ITU recommendation for the latter in any case.

Our initial interviews with stakeholders suggested demand for higher bandwidth links is growing strongly. Therefore, there is a reasonable case that international recommendations on channel sizes may be somewhat lagging users' emerging requirements for larger channels.

Interim conclusion

However, equally ComReg quite properly does not want to deviate from these recommendations without very good reason. Network equipment manufacture is a global enterprise and follows international standards; it is unlikely that equipment would be cost effective if manufactured with specifications particular to a variation in one country. Therefore, while it may use the discretion to merge channels given to it by CEPT/ECC recommendations, or allowing applications for multiple channels, ComReg should not define new, wider channels unless these are included in updated international recommendations.

6.1.2 Information policy

Coordination of different users within a band to promote efficient allocation of the spectrum can be supported via information made available at the application stage. ComReg has recently started providing operators with information on whether a channel is available before they submit an application[57], resolving the main issue with the application process (alongside the related problem of wait times) raised by stakeholders in the interviews. Nevertheless, further information on congestion (e.g. based on the probability of a typical link being accepted in a band, at a location), could benefit both operators and ComReg.

Measurings scarcity instead of closing bands

As noted above, ComReg currently does not provide for new licences in a congested area in Dublin in the 13 GHz and 15 GHz bands. However, as far as we are aware this approach does not take into account that links in those bands may be cancelled or moved and space may open up. Indeed, the data indicates that the number of links in these bands in Dublin has fallen over the last few years, as has the amount of spectrum in use.

[57] Various stakeholders mentioned in the interviews that they had not yet used this tool. We would encourage stakeholders to check whether the tool meets their expectations/requirements before commenting on what further information ComReg could make available.

Closing bands to further applications in this way is a very basic informational measure ("no space here – move on"). However, additional fine-grained information should help with more efficient planning and organisation. The current measure means that, as operators cancel their licences in the bands (e.g. to access 112 MHz channels in the 18 GHz or 23 GHz bands), the channels that are freed up could be inefficiently unused, whereas a finer information measure would allow users to apply for channels in the 13 GHz and 15 GHz bands when they become available.

We have seen evidence of scarcity/congestion in Dublin, but currently not so much in other areas. However, this is not to say that congestion issues will not arise elsewhere in the future, in particular with ever increasing bandwidth requirements and the potential for fixed links to support fibre networks in rural areas. Similarly, scarcity in Dublin might ease in the future (e.g. as fibre rollout reduces demand for microwave links). Information on congestion should be more systematic, so that it can adapt to these changes.

Notice periods before closing bands

Individual link licences last for one year, but can be renewed each year if the licensee complies with the licence conditions (including the payment of fees), and there are no potential changes to the fixed links bands that require the licence to be amended or cancelled. ComReg may need to make changes to some of the bands, such as clearing them (i.e. to make the 1.4 GHz or 26 GHz bands available for mobile use) or applying congestion charges, and in making these changes it should consider:

- expectations about on-going monitoring of scarcity and what happens to existing users if a band become scarce for the first time; and
- licence durations and renewal procedures (i.e. expectations of licences being rolled over).

In practice, this only requires ComReg to be systematic and transparent with how it makes changes.

6.1.3 Pricing

Where spectrum is scarce (i.e. where there is congestion, in this context), efficient allocation requires charging users for the long-run opportunity cost that their usage of spectrum for a particular fixed link causes. However, opportunity cost prices are difficult to estimate with any certainty. Therefore, focusing on

the information policy associated with individual link applications is more likely to be effective in coordinating users than attempting to put in place the theoretically optimal pricing structure. There is still value in ComReg reviewing the existing price schedule, but we cannot expect to calculate the opportunity cost prices associated with each possible link because:

- the interference impact of a fixed link being high specific to the particular path, antenna height and power levels of that link and characteristics of the impacted link; and
- the financial impact of denying another user's fixed link being difficult to forecast, as often the user could move to another band (when considered over a long enough time framework that equipment can be changed).

In practice, proxies that estimate opportunity-cost-based prices, such as the current congestion charge, are potentially useful, and there may be a case for making them dynamic (e.g. switching on or off as a measure of congestion crosses some threshold).

A full review of the fixed links pricing schedule will follow the initial consultation, these issues will be explored in more detail in our next report.

Ahead of the review of the guidelines and pricing schedule, we invite comments on:

- specific aspects of the existing guidelines and their technical parameters of the licence conditions that should be reviewed (i.e. any that may inhibit use of new technology);
- useful information that ComReg could provide (e.g. on congestion levels); and
- the structure of the pricing schedule (e.g. differences across bands, bands likely to be more or less valuable, congestion charging).

6.2 Block licences

In general, there are three key parameters need to be considered when assigning block licences:

- bandwidth;

- duration; and
- geographical extent.

Holders of block licences are allowed to deploy any number of fixed links, within the confines of these parameters, and only new sites need to be registered with ComReg. Licence holders are responsible for their own interference management, and links can be deployed quickly with no additional licence fee per link.

6.2.1 Advantages in high frequency bands

For some frequency bands, there may be advantages to block licensing if it is expected that there will be intensive use of fixed links at some locations and individual link licensing would be onerous or impractical. This is likely to be most relevant for higher frequency bands where there is a use case for dense cell applications where radio modelling of interference at a sufficiently fine geographical level may not be feasible.

Block licences at 26 GHz and above may also provide greater flexibility in establishing new links and reconfiguring existing links as customer demands change overtime for some use cases (e.g. advanced FWA). Whilst the 60 GHz unlicensed band may be useful for such new applications, unlicensed spectrum may be a poor alternative where customers need service level guarantees.

Can lead to unused spectrum

There are a number of potential advantages to the holder of a block licence, such as allowing for greater frequency reuse as operators manage interference themselves, better frequency management, guaranteed availability of links without delays inherent in individual link licence processing, and reduced total costs (e.g. equipment costs as fewer spares are required if an operator concentrates in one band, or because there is no marginal licence fee). However, these need to be balanced against the disadvantages of block licensing in potentially excluding technically feasible coexistence opportunities, leaving spectrum unnecessarily unused. For this reason, block licensing may be unattractive for lower bands where links tend to be longer and interference more predictable.

Optimality at a micro level

The benefits of block licensing are greatest where links are likely to be densely deployed. Therefore, there may be advantages to offering sub-national licences splitting urban centres and the rest of the country. This is analogous to the spectrum packaging issue for the 3.6 GHz band, though in some cases individual link

licences may continue to be more appropriate in rural areas. Moreoever, simple regional block licences are probably not appropriate, if the use case is concentrated in a much smaller area than that covered by the cities as defined in the 3.6 GHz award. Therefore, there may be a case for quite limited "micro" licences covering only a small part of an urban centre.

6.2.2 Assignment

Block licences area typically assigned by auction

Auctions (such as that successfully used in the 26 GHz block licence award) appear to be the most appropriate allocation procedure, as it is otherwise difficult to evaluate the potential opportunity cost of a long-term right to use specific frequencies. Reserve prices can be set to recover administrative costs with little concern if licences are then sold at reserve. Auctions also limit the number of specific license parameters needed which are simply assigned through auction mechanics; for example, operators can bid for the number of lots required for their desired channel size.

On the other hand, block licences are not suitable for all operators, as many do not have a sufficient number of fixed links to justify paying the higher auction price for a block of spectrum as opposed to individual links. While for others, block licences are ineffective as they may require a number of bands instead of a number of links in a single band (e.g. FWA to isolated customers).

A possible alternative is assigning a band 'manager' or a number of shared users to a block of spectrum. This has the benefit of providing those who need a few links with simplified coordination between the few users. This is essentially a variation on block licensing where usage is somehow shared by private arrangement. The block licensing regime should not preclude such arrangements forming; we note that holders of block licences previously awarded by ComReg are already able to lease out spectrum.

Current block licences

Currently, the MNOs hold all of the block licences, and would likely be interested in replacements when these expire, as well as new block licences at higher frequencies. However, other users have also expressed an interest in block licences (noting the additional benefits e.g. speed of deployment), and these operators may different preferences over block licence parameters (e.g. potentially being more interested in shared block licences than MNOs).

As mentioned in relation to the 32 GHz band, there is also a question of timing for the release of block licences as a replacement for 26 GHz licences. Firstly, if 5G use of the 26 GHz band is concentrated in cities, it may still be possible to use the band for fixed links elsewhere, but this is unclear at present. Secondly, users other than MNOs might want access to new block licences before 2028, while the MNOs may also want the licences early to allow a smooth transition to using a new band.

6.2.3 Costs of block licensing in already used bands

Most of the existing fixed links bands already contain a large number of links licensed to many different users. This means there is a large amount of equipment in use, which typically has quite a long asset life, and a tuning window that covers at most one band (in some cases only a sub-band). Therefore, reorganising a band in order to introduce block licences is likely to be very costly as it would require migrating a significant number of users across bands, with all of the migrated users needing to purchase large amounts of new equipment. Even existing users within a band who were awarded block licences might be required to move to a part of the band not covered by their existing equipment.

As a result, there is only likely to be a case for block licensing in greenfield bands (e.g. W-band, D-band, 32 GHz band), where no reorganisation is required. There is likely to be a strong case in these three bands, because the use cases meet the criteria set out above (i.e. dense deployments of links, making interference analysis difficult), or because the 32 GHz band could serve as a replacement for the 26 GHz block licences.

As mentioned above, there is still potential for block licensing in the 80 GHz band, where use cases may be suited to block licensing, but there is already a large number of links deployed in Dublin, where the benefits from block licensing, absent the need to reorganise the band, would be greatest. Overall, we consider that block licensing is much easier to introduce in bands that are currently empty.

6.3 Licence exempt / light licensing

6.3.1 Current licence exempt use

The 5 GHz, 17 GHz, 24 GHz and 60 GHz bands are available for use on a licence exempt basis currently, meaning that operators can use the spectrum without being granted a licence by ComReg, subject to power limits. It is unlikely that there would be a case for opening up further bands on a licence exempt basis unless these were identified in international harmonisation measures, as without standardisation there will not be sufficient competition or economies of scale in equipment manufacturing, and the band would not be used.

New network structure (e.g. mesh networks) where many links are deployed in a small area may suit licence exempt spectrum if interference issues are likely to be limited, as may be the case with short links in urban areas. Stakeholders have indicated that this could be the case for the 60 GHz band.

Providing licence exempt spectrum is straightforward, as ComReg merely needs to include all the bands harmonised for licence exempt use in its fixed links and SRDs framework. In principle, ComReg could attach additional conditions to licence exempt use, for example channelisation. That is, ComReg could provide a band plan (e.g. following Annex 2 of ECC/REC/(09)01 for the 60 GHz band), and require operators to use a defined channel, to reduce fragmentation of the band on occasions that multiple operators where using the band in the same location. However, it should only attach additional conditions if operators believe such conditions would be effective in improve coordination of licence exempt users.

In general, having as few conditions as possible on use of the spectrum is a major advantage to users of the licence exempt bands, as it allows them to deploy links as quickly and cost effectively as possible. Power limits are likely to be sufficient to prevent interference with users in neighbouring bands. Therefore, we do not believe that ComReg needs to make any changes to its existing licence exempt framework.

6.3.2 Light licensing

Of the stakeholders that use licence exempt spectrum, none have suggested that any changes to the framework are needed

to mitigate interference issues, and many have highlighted the benefits of the status quo in allowing them to deploy new links quickly and at little cost. Nor have any operators who do not use licence exempt spectrum, because they need the interference protection that comes with the licensed fixed links bands, suggested that particular alterations to the licence exempt framework would persuade them to use those bands. Nevertheless, it is appropriate to set out potential options for light licensing for completeness.

Registration requirements

If there were significant interference issues in the licence exempt bands that could be solved by simple coordination measures, ComReg could use a form of light licensing. A simple form of light licensing would be similar to the existing licence exempt model, but with registration requirements. Currently, registration is only required in the 5.8 GHz band, which is the part of the 5 GHz band with the highest permissible power limits. In this case, an operator would have to notify ComReg when it installed a new link (ComReg could require a range of variables to be recorded, which would include site coordinates, equipment used, and exact frequencies of the link), but it would not have to pay any fee, or wait for approval.

Light licensing of this kind would not provide any formal interference protection, but would simply be a means of collecting information on how much spectrum was being used at different locations. Anonymised data could be published, allowing some self-coordination between users (i.e. if an operator saw that the frequencies it intended to use were already in use over the same path, it could use a different part of the band to avoid interference arising in the first place).

Priority users in the event of disputes

A slightly more involved form of light licensing would attach rules to the registration requirements over whose link takes priority. In the UK, Ofcom's 'self co-ordinated licences'[58] are closer to the individual link licences currently provided by ComReg. Holders of these licences still pay a fee per link, per year, albeit at a much lower rate than standard licences, but Ofcom will not carry out interference analysis, meaning it is quicker for new link registrations to be processed. In this model, Ofcom attaches a date and time to each link, leaving operators to resolve interference issues between themselves, with the link installed earlier taking priority. If Ofcom then receives a

[58] Ofcom, 2013, 'OfW 369: Guidance Notes for Self Co-ordinated Licence and Interim Link Registration Process in the 64-66 GHz, 73.375-75.875 GHz and 83.375-85.875 GHz bands'

complaint, it removes the more recent link from the register. We note that the 64 – 66 GHz band was subject to this form of light licensing in the UK, but is now licence exempt[59].

Granting priority user licences is stronger than basic registration requirements, and would require ComReg to get involved if there were disputes between user. However, we expect that ComReg should continue with a licence exempt framework for all of the licence exempt bands unless operators believe light licensing (most likely in the form of registration requirements) would be helpful in one or more of them.

We invite views from stakeholders on whether any registration requirements or amendments to the technical conditions on use of the licence exempt bands are required.

[59] Ofcom, 2018, 'Decision to make the Wireless Telegraphy (Exemption and Amendment) (Amendment) (No.2) Regulations 2018'

7 Summary of interim conclusions

In this section we set out a summary of the main interim conclusions that we have reached following this initial phase of the project and our current recommendations. We note that these are preliminary rather than fixed views, and we welcome comments from stakeholders.

It is important to recognise that much of our recommendations are driven by international harmonisation (CEPT/ITU) and the availability/cost of equipment for each of the relevant bands. Any measures taken by ComReg should therefore be taken with this in mind.

Potential uses cases

We have identified the following use cases as the key current and future applications for fixed links in Ireland:

- narrowband telemetry and control;
- broadcast distribution;
- mobile backhaul;
- fixed wireless access;
- links within telecommunications core networks;
- advanced fixed wireless access; and
- specialist low latency links (e.g. for financial trading).

Overall, and although this will not apply to all users, we anticipate a general trend towards use of shorter and higher capacity links, coinciding with increasing bandwidth/speed requirements and continued roll-out of fibre. As such, we anticipate users to move into the higher bands, a trend that is already apparent in the licence data.

Demand for wider channel widths

- A number of stakeholders have expressed a demand for wider channels than are currently available in some of the fixed links bands, in particular the 11 GHz, 13 GHz and 15 GHz bands.
- In general we do not see any particular downsides to making wider channels available, where feasible and in line with international recommendations.

- ComReg should continue to adhere to CEPT/ITU recommendations on channel arrangements, but should also update its band plans to incorporate revised recommendations, and could consider using the option to merge channels set out in these recommendations, where there is a need for wider channels.
- In particular, the most recent ITU recommendations include channel widths of 112 MHz in the 15 GHz band, has not yet been adopted by ComReg but we anticipate this will happen in the near future.
- Efficient use of wider channels (whether new or existing) may be prevented if smaller channels are allowed within the same band and are positioned in a way that splits ('fragments') the unassigned frequencies into multiple blocks. ComReg may take this into consideration when new link licences are allocated to try and keep unassigned frequencies together. However, in reality there may be little that can be done to prevent fragmentation issues, due to the complexity of monitoring and organising the frequencies assigned.

Information vs. pricing to encourage efficient use

- There is currently congestion in some bands in the Dublin area, which has led ComReg to stop allocating new licences in the 13 GHz and 15 GHz bands and to charge a congestion fee for links in the 18 GHz and 23 GHz band within the congested area.
- For encouraging efficiency, the main emphasis, in our view, should be on providing current and potential users with regular, predictable information about emerging scarcity in particular bands at particular locations so that future links can be planned and congestion avoided where possible. ComReg has already started to implement this type of approach with its new tool for checking channel availability at the application stage.
- At present we only see evidence of congestion around Dublin. However, congestion issues may arise elsewhere in the future, in particular with increasing bandwidth requirements and the potential for fixed links use cases in rural areas. On the other hand, scarcity in Dublin might ease in the future with fibre

rollout. Ideally the pricing regime should adapt to changes in circumstances (e.g. a congestion charge could be "switched on" if scarcity becomes an issue in a particular band/region and switched off again if the congestion eases).
- Use of technology designed to improve efficiency of spectrum use should be encouraged. ComReg already allows for XPIC with no additional charge, and there are other technologies emerging that may help to ease or prevent congestion in heavily used bands/areas.

Bands that have been identified for 5G

1.4 GHz

- The 1427 – 1517 MHz band has been harmonised for ECS/MFCN, which covers the full upper parts of the 1.3 GHz and 1.4 GHz fixed links bands.
- We anticipate that it will be necessary to migrate fixed links from the band within the next three years, though not immediately, and therefore we would suggest ComReg provides early notice to existing users regarding its plans for the band.

26 GHz

- The 26 GHz band has been identified as a pioneer mmWave band for 5G and harmonised for MFCN, however the use case for 5G in the band is currently unclear, and there is already a sufficient amount of free spectrum to meet the requirement for 1 GHz to be made available in 2020.
- Therefore, we do not recommend ComReg makes any changes to the band at this time.
- We understand that ComReg is conducting a separate project in relation to the future use of the 26 GHz bands where this issue will be addressed further. In that regard, we believe it is important that ComReg provides current users with clear and sufficient notice of its plans as they become apparent.

42 GHz

- Work of harmonised technical conditions for the 42 GHz band is expected to be completed by July 2021.
- At present, there does not seem to be a need for any immediate action regarding the band, but users should be aware that it may be affected in future, and take this into account in their network planning decisions.

Opening new bands to fixed links

W-band and D-band

- ComReg is considering opening the D-band (130 – 134 GHz, 141 – 148.5 GHz, 151.5 – 164 GHz and 167 – 174 GHz) as part of this review, and stakeholders have also identified the W-band (92 – 114.25 GHz) as potentially useful for fixed links.
- These may be candidates for (localised) block licensing.
- Equipment/technology for these bands is still in development, and technical specifications (e.g. ETSI standards) are not yet available (although are expected by the end of this year).
- Therefore, there is no immediate need for the bands, and ComReg should wait for equipment developments and technical specifications before making them available, but they may nevertheless benefit from a rough road map regarding ComReg's plans for the bands.

32 GHz

- The 32 GHz band (31.8 – 33.4 GHz) was identified by stakeholders a potential replacement for the 26 GHz band, if it is no longer available for fixed links when the existing block licences expire in 2028.
- However, as there are potential use cases that are suited to block licences at these frequencies (i.e. advanced FWA), and in the interest of allowing a smooth transition between bands, ComReg may consider making the band available sooner.
- As with other bands that could be opened to fixed links, ComReg should provide a rough road map for the band.

The 17 GHz band can remain in use for fixed links

- Although the 17 GHz band was removed from ERC/REC 70-03 for short range devices (SRDs) in 2012 with the 15.4 – 17.3 GHz band identified by the ITU for radar applications, we understand that there is currently no reason for it to not be used for fixed links.
- We recommend that ComReg continues to make the band available for licence exempt fixed links use, unless we receive feedback from stakeholders to suggest that there is a good reason not to.

Block licences may be useful, but only in new bands

- There are benefits to block licensing (e.g. frequency reuse, lower cost of spares), but they are not suitable for all users, and must be traded off against the risk of sterilising use of the spectrum by other users that could coexist.
- Block licences are particularly useful in bands where there are dense deployments of links and interference modelling is difficult. Therefore, regional (or 'micro') block licences may be appropriate, possibly with individual link licences continuing in rural areas.
- The likely cost and complexity of regorganising bands that are already in use means the strongest case for block licences is likely to be in new bands, and potentially the 80 GHz band.
- Regional block licensing may be suitable for 26 GHz in the future, depending on developments regarding 5G in the band. In particular, if 5G is expected to require 26 GHz spectrum only to support urban hot spots, it may be feasible/desirable to allocate fixed links licences that cover the area (or multiple areas) outside the cities.

Coexistence with satellite use is unlikely to be a concern

- ComReg has highlighted that some of the fixed links bands are currently also used for satellite services connecting to earth stations. Our initial view is that coexistence of satellite and fixed links is unlikely to be a major concern, as coexistence measure are already in place. In particular, ComReg's licensing team already works with earth stations to avoid interference between satellites and fixed links.
- We note that ComReg is consulting on a new licensing framework for satellite earth stations and terminals in Q2/2021 which should provide an opportunity to more generally the needs and requirements of the satellite sector.

Annex A Current licensing regime in Ireland

In this annex we set out the fixed links licensing framework currently applied by ComReg in Ireland.

A.1 Radio link licences

A licence to keep and operate apparatus for wireless telegraphy is required under Section 3 of the Wireless Telegraphy Act 1926. Under the Wireless Telegraphy (Radio Link Licence) Regulations 2009[60], ComReg grants one year rolling licences to install and operate a single fixed link between specified sites (two in the case of P-P links, more for P-MP) using spectrum in a specific channel (frequency range). The definition of an individual link licence and the application process are set out in ComReg's fixed links guidelines.

Fixed links mostly use frequency division duplex (FDD) technology, and the licence specifies the transmit frequencies (i.e. whether the operator transmits over the lower frequency, 'transmit high', or higher frequency, 'transmit high' channel of the duplex pair). The right to operate a fixed link granted by this licence is subject to the licensee's adherence to technical conditions, including:

- site height above sea level and site coordinates;
- maximum transmitter power and emission designation;
- antenna gain, beamwidth, height above ground and polarisation (for standard links the licence specifies whether the dual or horizontal polarisation should be used, but ComReg also grants dual polarisation links); and
- frequency channel.

ComReg also grants temporary licences, which last up to six months and cannot be renewed. Temporary licence fees are applied pro rata to the annual licence fee using the number of months for which the licence is granted (i.e. the fee for a

[60] http://www.irishstatutebook.ie/eli/2009/si/370/made/en/print

temporary licence granted for less than one month is treated as if it were a one month licence for the purpose of fee calculations only).

A.1.1 Spectrum available and channel arrangements

The ECC, CEPT, and ITU give recommendations on the bands to be made available for fixed links as well as specific channel arrangements for different channel widths in each of those bands.

The recommendations set out proposed channel arrangements based on a set of 'recommended' channel widths to offer, but for some bands also suggest that National Regulatory Authorities (NRAs) may consider making available wider channels by merging smaller adjacent channels. For example, for the 13 GHz band, CEPT Recommendation 12-02 E[61] proposes channel arrangements for systems with carrier spacings of 1.75 MHz, 3.5 MHz, 7 MHz, 14 MHz and 28 MHz. However, it also states that "*CEPT administrations may consider merging any of two adjacent 28 MHz channels…to create one 56 MHz channel, with centre frequency lying in the central point of the distance between the merged channels*".

ComReg generally follows the CEPT and/or ITU recommendations on both which bands to make available and the channel spacing to be applied. These either have been updated recently (ITU recommendation now includes 112 MHz channels at 15 GHz), or are currently under review (in the case of the ECC).

Table 1 lists the bands in which ComReg currently issues individual link licences, detailing

- the frequencies available;
- the channel sizes offered by ComReg;
- the suggested range of channel sizes set out in the CEPT/ITU recommendations (separating out the channel sizes that may be offered via a merging of adjacent smaller channels); and
- the relevant CEPT/ITU recommendations.

[61] https://www.ecodocdb.dk/download/37dcc204-ccf0/REC1202E.PDF

Table 3 Fixed links bands for individual link licences

Band (GHz)	Available bandwidth in Ireland	Channel spacing in Ireland	CEPT/ITU proposed channel spacing	CEPT/ITU recommendation
1.3	1370-1375 MHz & 1512-1517 MHz	0.25, 0.5, 1 MHz	0.025, 0.25, 0.5, 1, 3.5 MHz	CEPT– T/R 13-01 E (2010) – Annex A ITU-R F.701 (1997) & ITU-R F.1242 (1997)
1.4	1375-1385 MHz & 1427-1437 MHz	0.25, 0.5, 1 MHz	0.025, 0.25, 0.5, 1, 3.5 MHz	CEPT– T/R 13-01 E (2010) – Annex B ITU-R F.701 (1997) & ITU-R F.1242 (1997)
2	2025-2110 MHz & 2200-2290 MHz	3.5, 7, 14 MHz	1.75, 3.5, 7, 14 MHz	CEPT– T/R 13-01 E (2010) – Annex C ITU-R F.1098 (1995) & ITU-R F.1248 (1997)
6 (lower)	5.925-6.425 GHz	29.65 MHz	29.65 MHz Via channel merge: 59.3 MHz	CEPT– ERC/REC 14-01 (2015) & CEPT/ECC/REC (14)06 (2015) ITU-R F.383 (2013)
6 (upper)	6.425-7125 GHz	20, 40 MHz	3.5, 7, 14, 20, 30, 40 MHz Channel merger: 60, 80 MHz	CEPT– ERC/REC 14-02 (2014) & CEPT/ECC/REC (14)06 (2015) ITU-R F.384 (2013)
7 (lower)	7.125-7.425 GHz	14, 28 MHz	1.75, 3.25, 7, 14, 28 MHz	CEPT– ECC/REC/(02)06 (2015)– Annex 1 ITU-R F.385 (2012)
7 (upper)	7.425-7.725 GHz	7, 14, 28 MHz	1.75, 3.25, 7, 14, 28 MHz	CEPT– ECC/REC/(02)06 (2015)– Annex 1 ITU-R F.385 (2012)
8 (lower)	7.725-8.275 GHz	29.65 MHz	28, 29.65 MHz	CEPT– ECC/REC/(02)06 (2015)– Annex 1 ITU-R F.386 (2013)
8 (upper)	8.275-8.5 GHz	3.5, 7, 14 MHz	3.5, 7, 14, 28 MHz	CEPT– ECC/REC/(02)06 (2015)– Annex 1 ITU-R F.386 (2013)
11	10.7-11.7 GHz	40 MHz	28, 40 MHz Via channel merge: 56, 80, 112 MHz	CEPT– ERC/REC 12-06 (2019) ITU-R F.387 (2019)

13	12.75-13.25 GHz	3.5, 7, 14, 28, 56 MHz	1.75, 3.5, 7, 14, 28 MHz Via channel merge: 56 MHz	CEPT– ERC/REC 12-02 ITU-R F.497
15	14.5-15.35 GHz	3.5, 7, 14, 28, 56 MHz	3.5, 7, 14, 28, 56 MHz 112 MHz (ITU)	CEPT– ERC/REC 12-07 (1996) ITU-R F.636.5 (2019)
18	17.7-19.7 GHz	27.5, 55, 110 MHz	13.75, 27.5, 55 & 110 MHz Via channel merge: 220 MHz	CEPT– ERC/REC 12-03 (2019) ITU-R F.595 (2012)
23	22-22.6 GHz & 23-23.6 GHz	3.5, 7, 14, 28, 56, 112 MHz	3.5, 7, 14, 28, 56, 112 MHz Via channel merge: 224 MHz	CEPT– T/R 13-02 (2019)– Annex 1 & Annex 4 ITU-R F.748 (2001)
26	25.277-25.445 GHz & 26.285-26453 GHz	3.5, 7, 14, 28 MHz	3.5, 7, 14, 28 MHz	CEPT– T/R 13-02 (2019)– Annex 2 ITU-R F.748 (2001)
28	27.9405-28.4445 GHz & 28.9485-29.4525 GHz	3.5, 7, 14, 28, 56, 112 MHz	3.5, 7, 14, 28, 56, 112 MHz Via channel merge: 224 MHz	CEPT– T/R 13-02 (2019)– Annex 3 & Annex 5 ITU-R F.748 (2001)
31	31-31.3 GHz & 31.5-31.8 GHz	3.5, 7, 14, 28 MHz	3.5, 7, 14, 28 MHz	CEPT– ECC/REC/(02)02 (2010)– Only for 31-31.3 GHz ITU- R F.1569 (2002), ITU- R F.1570 (2010), ITU- R F.1607 (2003), ITU- R F.1609 (2006, (2010) & ITU- R F.1612 (2003)
38	37-39.5 GHz	3.5, 7, 14, 28, 56, 112 MHz	3.5, 7, 14, 28, 56, 112 MHz Via channel merge: 224 MHz	CEPT– T/R 12-01 (2019) ITU-R F.749 (2012)
42	40.5-43.5 GHz	7, 14, 28, 56, 112 MHz	7, 14, 28, 56, 112 & 224 MHz	CEPT– ERC/REC/(01)04– Annex 5 (2014) ITU-R F.2005 (2012)
71/80	71-76/81-86 GHz	250, 500, 750, 1000, 1250, 1500, 1750, 2000 MHz (FDD); 250, 500, 750, 1000, 1250,	250, 500, 750, 1000, 1250, 1500, 1750, 2000 MHz (FDD); 250, 500, 750, 1000, 1250, 1500,	CEPT– ECC/REC/(05)07 (2009) ITU-R F.2006 (2012)

	1500, 1750, 2000 MHz (TDD)	1750, 2000 MHz (TDD)

A.1.2 Application/licensing process

Radio link licences (both for P-P and P-MP) are granted as one year licences, renewable annually or temporary licences up to a maximum of 6 months. Potential licensees may apply for a new link licence at any time, and applications are processed on a first come first served basis.

Application process

To acquire a new individual link licence, an applicant is required to complete an XML form, requesting use of a specific channel within their chosen band between two geographic points, and providing other information (e.g. antenna specifications) relevant to interference analysis. ComReg then checks that a candidate link satisfies the parameters as detailed in the Guidelines and will not interfere with any existing links licensed to other fixed links users,[62] taking into account a number of parameters such as the locations, frequencies, direction and power levels of the links. In the event that a link applied for is likely to cause interference to existing licensed links, ComReg will suggest an alternative channel within the band, if one is available, otherwise the applicant will have to submit a new application for a different band.

Licence renewal and amendment

Once a licence has been assigned the licensee can renew for the following year, which ComReg will accept if the fees for the following year have been paid in full, the link is operating according to the conditions of the licence, and there are no changes to the fixed links bands or their technical conditions being considered or implemented that would prevent ComReg from renewing the licence. If the licence has not been renewed prior to the its expiry date, it lapses automatically and cannot be re-instated.

Licences may be amended (e.g. if the technical characteristics of the link need to change in order to facilitate use of new equipment) subject to payment of any additional fees that would be due under the new licence specification e.g. in relation to increased bandwidth or a change in frequency.

[62] Note that the interference analysis ignores links already used by the applicant, so it is the responsibility of the applicant to ensure that the new link and its current operations do not interfere with one another.

The radio links guidelines

Beyond ensuring that all licensed links can coexist with each other, there are a number of measures already in the fixed links guidelines that support the efficient use of spectrum in the bands. These include rules applied at the application stage, conditions on the licence, and guidance that promotes the use of up to date technology.

Minimum path length requirements prevent operators using bands with favourable propagation characteristics that they do not need. For example, applications for links covering less than 9 km in the 13 GHz and 15 GHz bands will only be considered in exceptional circumstances such as high/low conflicts.

All links using the same channel within a certain distance of each other must either be transmit high or transmit low; a high/low designation conflict occurs when this would not be the case (e.g. a user applies to applies for a link that would transmit using the higher frequency channel when an existing link in the same location is transmitting using the lower frequencies). The guidelines specify the search radius for each band (500 m in the 13 GHz band and below, 400 m at 15 GHz, 300 m at 18 GHz, and 100 m in the 23 GHz band and above), and applicants should consult ComReg's high/low database to check if links are transmit high or transmit low within this radius of a site before applying. ComReg will not licence a link if there is a high/low conflict.

Some measures are particularly relevant to operators with high bandwidth requirements, or a large number of fixed links in their networks:

- Dual polarisation links allow operators to use both horizontal and vertical polarisations over the same channel. There is no additional licence fee for a dual polarisation link compared to a standard, single link, and dual polarisation is now mandatory for all new applications where more than one link is required over the same path, using the same frequency channel.
- ComReg will not assign separate frequencies for standby purposes, but does encourage other network planning measures to improve network resilience, such as:
    1. routing diversity (e.g. ring or mesh network architectures); and
    2. radio equipment redundancy for a given frequency channel.

All equipment must also be in compliance with the European Radio Equipment Directive[63], and meet the ComReg's minimum equipment requirements. To allow ComReg to check this, applicants must include a ComReg Equipment Reference Code in their applications, or complete an equipment code registration form if the equipment is not registered in ComReg's database. The minimum equipment requirements include a:

- transmission capacity requirement;
- minimum antenna requirement; and
- mandatory equipment class.

The equivalent isotropic radiated power (EIRP) allowed is another technical condition specified on an individual link licence. An applicant should request the minimum EIRP necessary for the propagation availability and capacity of the link, and should submit the path calculations used to arrive at this value as part of its application, using the parameters set out in ITU-R recommendations listed by ComReg in the guidelines.

ComReg encourages the use of adaptive coding and modulation (ACM) to mitigate the interference received on a link. The guidelines require that a reference mode should be defined for the fixed link in line with ETSI standards. This reference mode should be capable of delivering the core bit rate (high availability traffic), and utilise the fade margin when possible to increase the data rate (for lower priority traffic).

Information available to applicants

Until early 2020, applicants did not know whether a channel was available or not when preparing an application. This lead to situations (as reported by some stakeholders during the interviews) where, even if an operator had no strong preferences over particular channels or was able to make use of alternative bands, the time taken to acquire a licence was delayed by the need to go back and forth with ComReg to identify a free channel. To mitigate this risk, some operators would submit multiple applications for different channels and/or bands at the same time in the hopes that at least one would be accepted and the others would then be either rejected or cancelled by the applicant. We note that this is consistent with the licensing data, which shows a steady stream of unprocessed applications. This behaviour needs to be kept in mind when interpreting the licensing data, as applications have not necessarily reflected true demand for spectrum.

[63] Directive 2014/53/EU

As applications are processed on a first come first served basis, there may be some increase in licence application processing times when there are spikes in demand for new fixed links.

New tool for applicants

In early 2020, ComReg introduced a frequency band usage checker that allows operators to check whether a given channel is in use in a 1 km, 5 km, or 10 km radius of a proposed site before submitting an application[64]. We believe that providing information like this will significantly help with the timing issues around the application process. In particular, it should avoid the situations highlighted above with operators needing to submit multiple applications (simultaneously or sequentially) to find an available channel, which would also lead to a reduction in the number of applications submitted. Although there may still be some issues around general processing times during busy periods, we would expect this problem to be somewhat alleviated by the reduced number of applications that need to be assessed.

In general, we believe that improvements to the information policy around individual link licence applications are among the most important tools ComReg has available to improve the efficiency of the application process. The response from stakeholders to the new tool provided by ComReg has been positive. Some have already used it and acknowledged its usefulness, whereas others (some of whom were not aware of it) are yet to make use of it but believe it is likely to significantly improve the application process

A.1.3 Fees

This section set out the annual fees that currently apply to individual link licences.

ComReg applies a congestion charge for links in the 18 GHz and 23 GHz bands where at least one end of the link is within the congested area. A high usage fee applies when a licensee has five or more links over the same path.

Table 4 sets out the standard individual link licence fees (i.e. when neither the congestion charge nor the high usage fee is required. Table 5 details the fees that apply for links that are within the congestion area or on a high usage path.

[64] See Chapter 5 of ComReg's Fixed Radio Link Annual Report, ComReg 20/93, https://www.comreg.ie/?dlm_download=fixed-radio-links-annual-report-for-2019

Table 4: Annual fee for a P-P link

Frequency band	0.25 – 3.5 MHz link fee (EUR)	3.5 – 20 MHz link fee (EUR)	20 - 40 MHz link fee (EUR)	40 – 2000 MHz link fee (EUR)
< 1 GHz[65]	750	NA	NA	NA
1.3 – 15 GHz	1,000	1,100	1,200	1,500
17 – 37 GHz	750	825	900	1,125
37 – 39.5 GHz	550	605	660	825
42 - 80 GHz	100	110	120	150

Table 5: Annual fee for a P-P link in the congested area (18 GHz and 23 GHz bands only) or on a high usage path

Frequency band	0.25 – 3.5 MHz link fee (EUR)	3.5 – 20 MHz link fee (EUR)	20 - 40 MHz link fee (EUR)	40 – 2000 MHz link fee (EUR)
< 1 GHz	900	NA	NA	NA
1.3 – 15 GHz	1,200	1,320	1,440	1,800
17 – 37 GHz	900	990	1,080	1,350
37 – 39.5 GHz	660	726	792	990
42 - 80 GHz	120	132	144	180

For a P-MP licence, the annual fee is four times the annual fee for a P-P licence.

Fees for temporary licences are applied pro-rata based on the annual fees that would apply for a full licence and the number of months the temporary licence has been granted for.

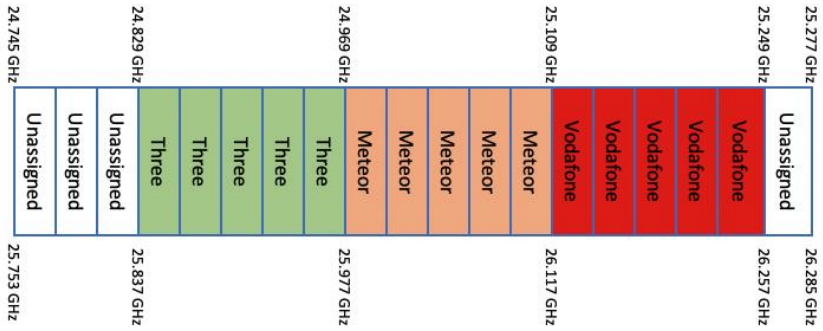
[65] ComReg no longer provides new licences for frequencies below 1 GHz, but there remains a small number of links still live in the sub- 1 GHz bands.

A.2 26 GHz block licences

ComReg has previously allocated national block licences for fixed links use in part of the 26 GHz band. While individual link licences allow an operator to use specific frequencies over a single link, the block licences give the licensee rights to use a range of frequencies anywhere in the country over any number of links.

At present, the three MNOs each hold five blocks of 2×28 MHz in the 26 GHz band that are licensed for P-P radio communications links on a national basis. The frequencies assigned are set out in the figure below.

Figure 11: Current 26 GHz national block assignments



These block licences were most recently allocated via auction in 2018, with a licence duration of 10 years (and an expiry date of 24 April 2028).

The applicable fees for these block licences comprise:

- an upfront fee (EUR 350k for Three and Meteor, EUR 550k for Vodafone[66]); and
- an annual spectrum usage fee of EUR 125k per operator (EUR 25k per 2×28 MHz block, index-linked to the CPI) for the duration of the licence.

This equates to a total of approximately EUR 5 million in fees across all three licensees.

National block licences for fixed links in the 26 GHz band were initially assigned in 2008, using a second price sealed bid combinatorial auction. 2×476 MHz of spectrum was made

[66] Vodafone paid an additional EUR 200k (determined as part of the award process) for being assigned specific frequencies within the band.

available, split into 17 blocks of 2×28 MHz[67] with a licence duration of 10 years. The available blocks could be used either for P-P or P-MP services, with the split between the uses determined based on the bids submitted in the auction rather than a predetermined division. Blocks assigned for P-P were to be located at the top of the available frequencies, with P-MP blocks at the bottom, and in the event that the final allocation involved both there was to be a guard block positioned between them (meaning a maximum of 16 blocks could be assigned in such a scenario). In addition, a competition cap that prevented any individual bidder from acquiring more than six lots was applied to protect downstream competition.

Ultimately, the auction resulted in 13 blocks being assigned to five different bidders, three of which were for P-MP use with the remainder for P-P. In particular:

- Vodafone was assigned four blocks for P-P;
- Three (then Telefonica) won three P-P and two P-MP blocks;
- BT ended the auction with two P-P blocks;
- Irish broadband was allocated a single P-P block; and
- Digiweb won one P-MP block.

Following the award,

- Digiweb surrendered its single P-MP block in 2009; and
- Three changed the two P-MP block licences it was awarded into P-P blocks (giving it a total of five P-P blocks) in 2012.

As the 2018 licence expiry date approached, ComReg made the decision to make new national block licences in the 26 GHz band available for a further ten-year period. Although 26 GHz had already been identified as a pioneer band for 5G, uncertainty over when it would be useable for 5G applications, the importance of P-P links to operators' networks, and the impending expiry of current licences meant that it was appropriate to reallocate fixed links block licences and avoid disruption to current services.

However, to avoid a situation in which some bidders viewed the award as an opportunity to gain an option to use this spectrum for 5G mobile services (which may have led to a distorted and

[67] A total of 18 2×28 MHz blocks were available, but the highest frequency block would have been designated a guard band in the event that all other lots were assigned.

inefficient award process), ComReg imposed licence conditions that precluded use of the new block licences for 5G deployment. More specifically, the spectrum was awarded for P-P use only, with demand for spectrum for P-MP considered unlikely at the time and the anticipation that P-P would be more compatible with future coexistence with 5G applications. This approach would avoid the risk of bidders bidding in the expectation of acquiring an option to use the spectrum for 5G later on, but would still leave ComReg with a range of future options for meeting any harmonisation obligation without unfairly favouring existing P-P national block licensee in the band, including (but not limited to):

- the possibility of issuing 5G rights of use as an overlay in parallel with existing P-P usage; and
- the possibility of providing an option for P-P licensees to liberalise licences to allow other uses (including 5G), but at an appropriate market-determined price.

The 2018 award was run using a sealed-bid combinatorial auction with a second-price rule (similar the format used for the 2008 award), with 19 blocks of 2x28 MHz available[68] and a competition cap of five blocks per bidder. As detailed above, the three MNOs were each awarded five blocks (i.e. at the cap), with the other four blocks remaining unsold.

A.3 Licence exempt spectrum

Operators are free to use spectrum in a number of licence exempt bands, subject to maximum power restrictions, without notifying ComReg (except in the 5.725 – 5.875 GHz band where registration is required as the power limits are less strict than the other parts of the 5 GHz band). There are no fees for using the licence exempt spectrum and operators may access it immediately. However, no interference protection is provided and users must coordinate with one another to avoid interference issues.

[68] The 19 blocks include the same blocks as in the 2008 award (with the top block no longer required to be a guard block if all others are sold) and an additional block at the lower end of the band that previously formed a guard band between the national block licences and spectrum in the band used for FWALA.

The bands currently available for fixed links on a licence exempt basis are set out in Table 6, along with the maximum power limits that apply and the relevant international harmonisation decisions.

Table 6: Licence exempt bands

Band (GHz)	Maximum Permitted Radiated Power / Field Strength	Harmonisation decisions	Notes
5.15 – 5.35	200 mW mean EIRP Power Density: 10 mW/MHz in any 1 MHz band	2007/90/EC 2005/513/EC ECC/DEC/(04)08 ERC/REC 70-03	Indoor use only We refer to the first three as the '5 GHz band'
5.47 – 5.475	1 W mean EIRP Power Density: 50 mW/MHz in any 1 MHz band	2007/90/EC, 2005/513/EC ECC/DEC/(04)08 ERC/REC 70-03	
5.725 – 5.875	2 W EIRP (Max mean) Power Density (Max mean EIRP): 100mW/MHz	ECC/REC (06)04	Registration required
17.1 – 17.3	100 mW EIRP		
24 – 24.25	100 mW EIRP	2006/771/EC 2011/829/EU 2013/752/EU ERC/REC 70-03	
57 – 71	40 dBm e.i.r.p., 23 dBm/MHz e.i.r.p. density and maximum transmit power of 27 dBm at the antenna port or ports	(EC)2019/1345 ERC/REC 70-03	Applies to indoor and outdoor applications
57 – 71	55 dBm e.i.r.p., 38 dBm/MHz e.i.r.p. density and transmit	(EC)2019/1345 ECC Report 288	Applies only to fixed outdoor installations

	antenna gain ≥ 30 dBi	ERC/REC 70-03

The licence exempt bands with the most spectrum available are:

- the 5 GHz band (the most used licence exempt band according to the operator RFI responses) which is predominantly used as a low-cost alternative to the licensed frequencies when interference protection is not important e.g. some FWA operators use the 5 GHz band, particularly in rural areas; and
- the 60 GHz band, which has considerably more spectrum available than the others and may be important in the future for supporting localised high capacity services.

60 GHz

Propagation of radio waves in the 60 GHz band is limited because of oxygen-absorption attenuation favouring reduced requirements for frequency coordination. Therefore, applications in the 80 GHz band have been more common, while the 60 GHz band is harmonised for licence exempt use.

In its most recent RSMSS, ComReg identified the 'V-band' (60 GHz) for review; previously only the 57 – 64 GHz band was available for fixed links, while 64 – 66 GHz was restricted to outdoor use. Since that RSMSS was published in 2018, CEPT has completed a review of higher power applications and frequency separation below 71 GHz, and has updated ECC/REC/70-03 accordingly. Following this, ComReg has made the full 57 – 71 GHz available for licence exempt outdoor use.

In 2018, the RSPG published its second opinion on 5G networks considering the 66-71 GHz bands as priority in terms of studies for second stage mm-Wave 5G bands. As a result of the WRC-19, Resolution 241[69] made available the 66-71 GHz band for use by terrestrial component of International Mobile Telecommunications (IMT). The resolution also notes that administrations wishing to implement other applications in the band should consider coexistence between IMT and other applications. Finally, it invites the ITU to develop harmonised frequency arrangements as well as recommendations and/or reports to ensure the efficient use of the frequency bands

[69] WRC-19, Resolution 241. https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.14-2019-PDF-E.pdf

through coexistence mechanisms between IMT and other services.

Annex B Stakeholder interviews and RFIs

As part of the project, DotEcon and ComReg conducted interviews with a number of fixed links stakeholders, including existing users and equipment manufacturers. The interviews have been a valuable source of information for establishing our understanding of the fixed links regime in Ireland. In this section we provide a summary of the key points raised in the interviews.

B.1 Demand and usage

Stakeholders explained their current use of fixed links, and how they expect their own and industry wide demand to change in the future.

Many stakeholders highlighted increasing bandwidth requirements to meet the need for faster speeds.

For a number of users, future demand is also likely to be heavily influenced by the rollout of fibre and development of new technologies. There appeared to be a general consensus that whilst the number of links might fall slightly (i.e. due to increased use of fibre), bandwidths per link will increase, the average link length will get shorter, and more use will be made of the higher frequency bands.

Bands up to 8 GHz

Lower frequency bands are typically used by particular operators that don't necessarily need high capacity but require very long links and high reliability. Although some interviewees suggested that they have occasionally found it difficult to find an available link in these bands, there does not appear to be any significant spectrum scarcity.

11, 13 and 15 GHz bands

The 11 – 15 GHz bands are widely used, with the 13 and 15 GHz bands being congested, especially around Dublin:

- Some operators highlighted that increasing capacity requirements are difficult to meet with the relatively low maximum channel widths available in these bands, compared with those offers in higher frequency bands. There is increasing demand for 112 MHz channels, but currently this is only possible (in the 13 and 15 GHz bands) by running two 56 MHz channels side by side.

- It was suggested that if ComReg does not allow for larger channels then demand in these bands will fall (with operators moving into the higher frequency bands), leaving prime spectrum inefficiently unused. However, many stakeholders do not believe that congestion is likely to ease in the future.
- The most common explanation for the high demand in the 13 GHz, 15 GHz bands (as well as the 18 GHz and 23 GHz bands) is predominantly due to the combination of available capacity, reliability and the mid-long range of links they can accommodate; this makes them particularly useful for reaching Dublin from a number of key high sites with good visibility to the city centre (e.g. Three Rock).

18 GHz and 23 GHz bands

There seems to be a consensus that there will be a growing demand for links in the 18 GHz and 23 GHz bands, in part due to the roll-out of multi band technology solutions that allow for pairing these bands with higher frequency spectrum (e.g. in the 80 GHz band) to achieve high capacity links over mid-range distances. Given the relatively high current use of the bands there is a risk of congestion.

26 GHz band

The 26 GHz band is mostly used by MNOs, who hold all of the block licences and the majority of individually licensed links in the band. Fixed links will eventually have to coexist with 5G or migrate to another band. With regard to the 26 GHz band, interviews made the following comments:

- It would be particularly costly for MNOs if they had to return their 26 GHz block licenses, which they use for a large and increasing share of their fixed links (in particular as individual links are moved into to block licences).
- Various bands were suggested as alternatives for the 26 GHz band in the event that block licences were ultimately no longer available. These include the 28 GHz, 32 GHz and 38 GHz bands.
- The 26 GHz spectrum could be used in bonded links with 80 GHz.

80 GHz band

The E-band has seen considerable growth in demand, and stakeholders expect this to continue:

- There is a consensus that the 80 GHz band is increasingly popular and a general expectation that this band will be particularly important for 5G backhaul. It also offers high capacity at a relatively

low cost, based on the current fee structure in Ireland (especially when evaluated per Gbit/s that can be achieved).

- On its own, the 80 GHz band is suitable for relatively short (but high capacity) links in urban areas and will be increasingly used for fronthaul to support complex 5G network structures.
- It can also be used in combination with other bands (as a multi carrier/band solution) to support both high capacities and relatively long link lengths and availability (with the 80 GHz band providing capacity and a lower frequency band providing redundancy/resilience).
- ComReg notes that we should explore the implications of multi-band solutions for its minimum availability requirements in its fixed links guidelines.
- Average link lengths are expected to decrease, so it may also be useful in more rural areas in future (e.g. as fibre presence expands, short microwave hops will be required to connect sites to a fibre node).
- A number of stakeholders raised concerns that the E-band might soon become congested, in particular in urban areas. Others believe that there is sufficient spectrum available in the band for congestion issues to still be some way off. The W-band is a potential alternative if the 80 GHz band does become congested.

Licence exempt spectrum

Licence exempt spectrum does not seem to be particularly popular as it generally does not assure protection form interference and guaranteed availability of the spectrum offering little reliability for many uses cases.

Furthermore, there is very limited amount spectrum in the existing license exempt bands which does not really tackle capacity requirement concerns and needs (although we need to bear in mind that the interviewees were the larger users of fixed links and probably not the organisations we might typically expect to use licence exempt spectrum).

Our understanding is that licence exempt spectrum may be relatively more useful in rural areas, for smaller operators focused on providing a low cost service, or at higher frequencies. Nevertheless, some RFI respondents have installed a large number of links, mostly in the 5 GHz band, often to provide low capacity P-MP broadband access. Their main reason

for doing is that these links can be deployed quickly and cheaply.

P-MP links

There are currently relatively few P-MP links licensed by ComReg:

- Most operators expect demand for P-MP links to remain low and have no plans to make use of them.
- One interview noted that there had been P-MP block licences allocated prior to the 2018 award, but these were subsequently either returned to ComReg or converted to P-P licences;
- However, a number of stakeholders believe that P-MP will be relevant in the future, for example using a mesh configuration in the (licence exempt) 60 GHz band. Current P-MP links are also concentrated in the licence exempt bands.

B.2 Impact of 5G

The 1.4 GHz and 26 GHz bands

The 1.4 GHz and 26 GHz bands have been identified for 5G. A large number of the stakeholders interviewed do not use either of those bands and did not express any strong opinions or concerns about the introduction of 5G. However, we did receive some feedback, in particular:

- Some interviewees believe that ComReg should consider relocating the 26 GHz band fixed links users before vacating it for 5G purposes;
- Some bands (in particular the 28 GHz, 32 GHz and 38 GHz) were suggested as potential substitutes for the 26 GHz band, should it be used exclusively for 5G (i.e. ComReg should consider block licensing for fixed links in these bands);
- One interviewee believes that there is unlikely to be a business case for 5G in the 26 GHz band, due to the severely limited indoor penetration at those frequencies and the cost of deploying additional sites/outdoor antennas. The interviewee believes that the band would be better used for fixed links.

Backhaul using higher frequency bands

5G backhaul will contribute significantly to increased demand in the next few years:

- One interviewee thinks the D-band will be particularly important for complex 5G networks requiring channels of over 2000 MHz;

- The 60 GHz band is potentially useful for small cells but is not harmonised to the same extent as the 80 GHz band. Furthermore it is license exempt, which is much less reliable and therefore less used by many operators.

B.3 Fibre

We received a number of comments in relation to the impact/consequences of fibre rollout for fixed links:

- The majority of stakeholders are of the view that fibre will not completely replace the need for fixed links.
- A number of the microwave links are likely to be replaced with fibre (in particular in the lower frequency bands within the cities). However, there will always be places that fibre can't reach, and wireless links will be required to reach those sites and connect back to the fibre network. These links are likely to become shorter on average (as the reach of the fibre network increases), but operating with a much higher capacity.
- The hard to reach locations may be rural sites (e.g. mountain tops, where running a fibre cable may be uneconomic or practically difficult) or buildings within the cities (where access might be restricted).
- A number of interviewees suggested that fibre and fixed links are in some ways likely to be complements:
    1. Demand for wireless links as a backup to a primary fibre connection will increase, for land/air resilience or because installing a second fibre cable will be expensive.
    2. As the fibre network expands, this could allow new businesses to open in rural areas, and for these businesses a wireless backup is likely to be more cost effective than a second fibre connection.
- The NBP will have a significant effect on the availability of fibre, and therefore a impact on the demand for microwave links;
- Rollout of fibre in rural areas so far has been relatively slow and some stakeholders expect that multi-carrier solutions will be the main approach to increase

capacities (whilst maintaining link lengths). However, as fibre rollout increases over the long run, we can expect less pressure on some of the bands used for multi-carrier solutions.

The impact of fibre will depend on its availability and will vary across bands. Ultimately, there will always be some demand for microwave links for certain services such as fixed networks or to serve corporate clients. Geographic variation in the impact of fibre is also likely, for example as a lot of mountain top sites are difficult to connect to fibre so FTTP services may require microwave backhaul for connecting to these remote sites.

Stakeholders expressed some conflicting views on fibre availability and deployment:

- some believe that fibre will be widely available soon, at least in urban areas; whereas
- others were more skeptical and believe that it will take some time before it is up and running for effective 5G deployment (in which case there will be a continued reliance on high capacity microwave links).

B.4 Substitutability between bands

In relation to substitutability, stakeholders made a number of comments/observations:

- For most of the fixed links operators interviewed, there is a range of bands that they can feasibly use for a particular application. For a given link/use case, the range is typically limited to a subset of the full set of fixed links bands due to needing links that can cover a certain distance and/or provide a minimum capacity.
- Outside of the required range, moving to lower frequencies can be difficult due to capacity constraints, whereas going into higher frequencies can be problematic where longer link lengths are required;
- There are also short run barriers to switching existing links to other frequencies due to the costs of replacing equipment. Radios are typically tuneable only within a certain sub-band of a particular frequency band, and moving the link out of the tuning range of the equipment requires a

replacement of the hardware. Therefore, even moving to a different frequency within the same band can be expensive. The extent to which the equipment is returnable varies across frequency bands and vendors. So whilst a new link could be put into one of a range of bands, it is not so easy to migrate an existing link to different frequencies.

- Equipment stock can also play a role in an operators willingness to utilize one band over another.
- Equipment is only a constraint on substitution in the short run (since hardware will be regularly replaced), but link length constraints are permanent (e.g. a single 80 GHz link will not cover the same distance as a 13 GHz link).
- Substitutability across a limited number of bands is possible, subject to having equipment stock for the various bands otherwise it is quite costly (sparing is a large cost for many fixed links operators).
- Although moving between adjacent bands may be feasible (i.e. equipement is available) and desirable for some operators particularlty in congested bands, operators who are renting tower space from third parties may face increasing tower space rental costs, if migration to a new band requires larger dishes.
- Likewise, the equipment for some advanced techniques that allow users to access greater bandwiths (particularly MIMO) will also come with increased tower rental costs (e.g. because more antennas are required).

B.5 Equipment

Current equipment Regarding the equipment used widely at the moment:

- There is generally little variation in equipment costs across different bands.
- Some respondents mentioned that equipment is a little more expensive for the lower the frequencies (where larger dishes are required etc.);
- The asset life of the equipment is not a key driver of when it is replaced (i.e. replacement of links is driven by end user demand);
- Operators will often hold spare equipment to cover various bands;

- Equipment is typically tuneable within a given band, or sub-band, but not really across different bands;
- Equipment for higher frequency bands allow for wider tunning ranges than lower bands without a significant risk of interference; and
- Some equipement, such as the E-band, covers the whole band which reduces the overall number of spares the operators need to stock to access a large number of frequencies albeit at a higher equipement cost.

Technology developments

Stakeholders also discussed recent and expected technological developments:

- All of the equipment manufacturers explained that there is a range of new techniques available to increase spectrum efficiency (e.g. LoS MIMO, multi-carrier technology, and advanced frequency re-use).
- Some of these technologies have been possible for a long time, but have only recently become commercially available.
- Technology that becomes available over the coming years may develop existing techniques.
- Equipment for the W-band and D-band will be made available in the next couple of years. ETSI standards for these bands have not yet been released but are expected within the next year or so.
- The W-band is the natural successor to the E-band, so there is some expectation that technology for that band will be available sooner than technology for the D-band. Other respondents, however, believe the D-band is likely to become important earlier than the W-band.

Wider channels vs channel aggregation

Various operators expressed a demand for wider channels in some bands:

- Most respondents have acknowledged the increasing demand for larger channels (in particular 112 MHz or even 224 MHz channels) that are crucial for 5G backhaul and satisfying demand for faster connections, in particular in the short to medium term while fibre availability is still limited.
- In bands where these wider channels are not currently available, some operators have been using two contiguous 56 MHz channels to simulate a 112 MHz channel.

- It was recognised that technology developments are supporting additional capacity requirements in other ways, such as:
    1. XPIC configurations allows for running dual polarisation links over a single channel (this has been available and used in Ireland for a number of years).
    2. Multi-carrier solutions allow for aggregation of non-contiguous channels (which may even be in different bands).
    3. MIMO (but this requires special equipment and separate antennas and so is costly)
- However, having access to a single, larger channel is often preferred by users due to the lower cost relative to installing new, more complex, equipment.

Costs of new techniques

The newer equipment/technology is typically more expensive than the older, more basic, hardware:

- there are other additional costs associated with some techniques (e.g. MIMO requires more tower space);
- so operators would often prefer to have access to wider channels than change equipment; however
- the equipment manufacturers explained that a lot of the new techniques/high end equipment (in particular multi-carrier options) have a lower total cost of ownership (e.g. it may come down to operators' views on capex/opex balance).

Other concerns

An operator raised the concern that if there is no availability for larger channels (110 MHz) in the 11, 13 and15 GHz bands, manufacturers will not have any incentive to develop the equipment for using these bands in xpic configuration.

B.6 Licensing

Stakeholders were asked about their views on block licences, including the potential for additional block licences in bands other than 26 GHz, and whether there would be any interest in regional or shared block licences:

Block licensing

- A number of interviewees noted the clear benefits of block licences (both regional and national) in terms of

reliability, interference management, deployment speed, and equipment management (i.e. due to less need to stock equipment in a range of bands).
- Some highlighted that block licensing is only suitable for a operators with a sufficiently dense network within the area covered. Since block licences are generally quite expensive and for longer periods, they are less suitable for operators with fairly localised services and/or with client demand that varies on a year by year basis (e.g. fixed wireless).
- Although the situations in which block licences are useful seem to be specific to certain geographical areas, many larger operators are only interested in national licences.

Block licensing in other bands

Some stakeholders suggested that they would have an interest in block licences if they were introduced in bands other than the 26 GHz that were more suitable for their needs.

One interviewee suggested that the E-band would have been a good candidate for block licensing, allowing operators to manage interference themselves and allow greater use of the band, but believes it is a bit late for that given the existing use. However, block licensing spectrum in the currently unused W-band and D-bands might be appropriate when these become available.

Regional licence and greenfield bands

In certain cases, where fibre is sufficiently deployed in cities regional licences may be cost efficient as opposed to national licences to cover rural areas in particular where a band is yet to be licenced:

- One stakeholder considered that (regional) block licensing in the the D-band would be suitable, since the likely use of the band for short links in dense networks would create difficulties for managing interference on a link by link basis.
- In some cases, the areas with a high density of links in these high frequency bands might only cover 1-2 km^2, rather than a typical 'region';
- It may be difficult to define such small regions, and slight changes could have a significant effect on demand (e.g. around Dublin Docklands area).
- In bands were there are already many individually licensed links, one interviewee suggested using a hybrid system whereby block licences would be issued in part of the band and individual link licences would be available in the rest of the band;

Shared licences

- Some stakeholders expressed a tentative interest in potential shared block licences would be, with some suggesting they could make block licences more affordable for smaller/regional operators.

Stakeholders were also asked about the current interference protection offered by the current licensing regime. Most operators are satisfied with the interference protection provided by current licence conditions; interference issues are rare, but when they do occur operators often find it quicker to request a new channel, rather than wait for ComReg to investigate and resolve the problem. One interviewee suggested that light licencing could be introduced in bands from 60 GHz upwards, where it believes interference will be limited (due to short hop lengths and large amount of spectrum available) and difficult to police.

B.7 Making new bands available

The stakeholders offered views on the candidate bands identified by ComReg for this review (the D-band) and commented on further bands that could be opened up to fixed links (32 GHz and the W-band). All of these bands could be useful at some point, but operators would not be interested in the new spectrum above 42 GHz until equipment becomes available. Regarding particular comments on new bands:

- The W-band may be used as an alternative for the E-band when the E-band is full.
- The 60 GHz band can also be used in place of the 80 GHz band, but it is licence exempt, so increased risk of interference makes it harder to guarantee availability.
- The 60 GHz band is not harmonised to the same extent as the 80 GHz band, so it is not deployed as widely.
- One stakeholder suggested that the greater amount of contiguous spectrum available is the reason that D-band is focused on ahead of W-band, and that ComReg should not hurry to release these bands, as they will become important once 5G is mature.

B.8 Application process

Operators' views of the application process were generally positive, however many had experienced difficulties in finding an available channel in the past, therefore:

- All respondents seem to be happy with the option to check channel availability before applying (a feature introduced to the application system in 2020) and think that this feature is useful
- Some voiced concerns regarding the substantial varying time it takes to get an application processed, they think it takes too long in some cases affecting end-users.
- One operator raised the idea of introducing priority applications at a cost, noting that it was possible for ComReg to quickly process applications in exceptional circumstances.
- One stakeholder suggested implementing a 'preferred channel' approach, whereby an operator would always be assigned a particular channel if it was available at a site (but possibly an alternative channel at busy sites) and paying for individual links, which might be more realistic for E-band at this stage;
- Another operator suggested imposing a "use it or lose it" condition on congest bands.

Annex C Data analysis

This annex includes further analysis of ComReg's licensing data to that presented in Section 2.

C.1 Number of links

In this section we look at the number of links licensed over the period 2010 – 2020. The aggregate number of links, and the number of links licenced to MNOs and FWA operators in each band were discussed in Section 2, but here we break the trends down by user type, and by location. Apart from in the stacked charts, the graphs below count dual polarisation links as two links (as they are recorded in ComReg's database).

Figure 12: P-P links by region over time

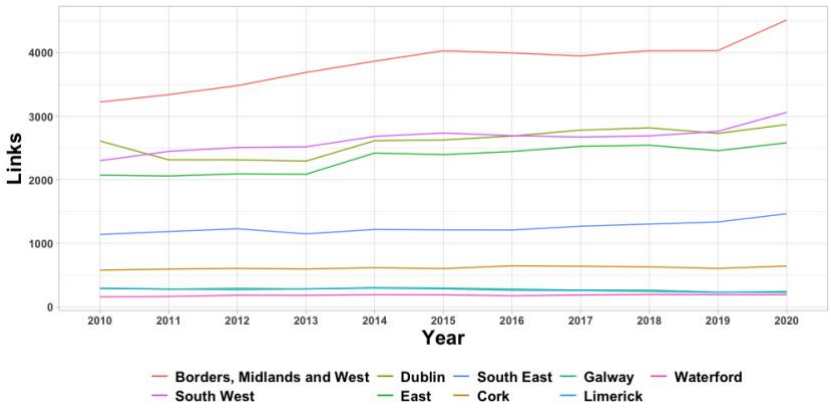


Figure 12 counts the number of links with at least one end in each of the regions defined by ComReg for its 3.6 GHz award[70]. The region comprising the West, Midlands, and Border Counties has more links than any other because it covers a large area, while the number of links in Dublin is comparable to the number in the South West (also a large geographical area), and greater than the other 'rural' regions.

[70] ComReg 16/71

Figure 13: P-P links by whether one, both, or neither end in the congested area

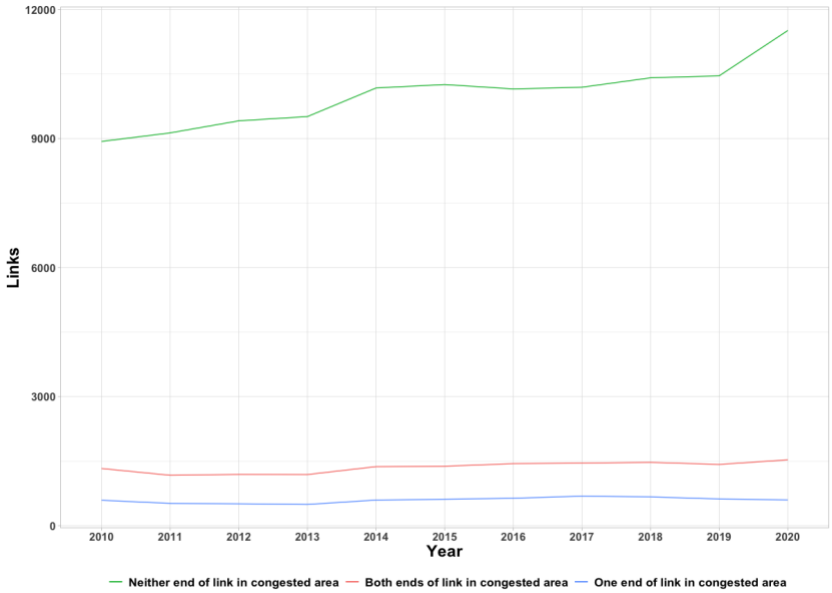


Figure 13 breaks out the trends in the number of links licensed dependent on whether one, both, or neither end of the link is in the congested area. It is based on the geographic area only, not the band (i.e. a 28 GHz link in Dublin might have one or both ends in the congested area, even though it would not face any congestion charge). The number of links outside of the congested area has increased substantially over the last ten years. Although the growth in the number of links in the congested area has slowed, this graph does not account for the fact that demand is concentrated in certain bands, which is what has led to congestion.

C.1.1 MNO links

Figure 14: P-P links individually licensed to MNOs over time

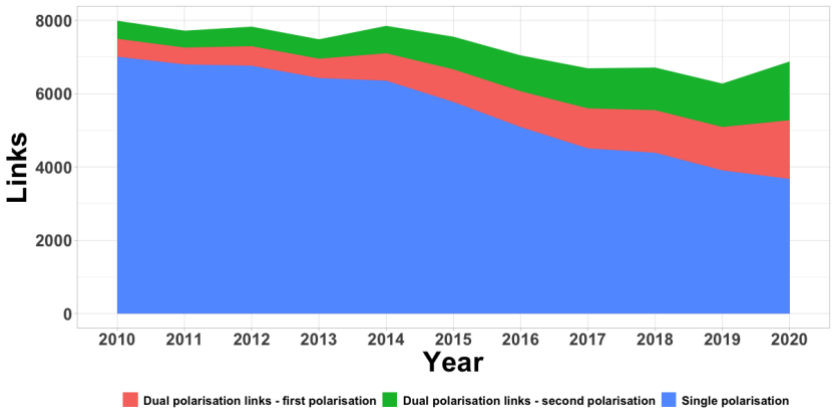


Figure 14, Figure 15, and Figure 16 present the total number of links licensed to MNOs, and the number of links by region:

- there is about a 15% reduction in the total number of individual links licensed to the MNOs
- this predates the most recent award of 26 GHz block licences in 2018, but the MNOs also held some of these block licences from the 2008 award, so transition onto block licences is a factor in the decline throughout this period;
- it may also be due in the main to increasing bandwidth requirements coming in with 4G, leading to increased use of fibre backhaul where feasible/economic; and
- the MNOs have increased their use of dual polarisation links, although the growth seems to have tailed off from 2017.

The decline in individually licensed links operated by the MNOs has occurred in Dublin (including a clear, steady decline in the congested area) and most rural areas.

Figure 15: P-P links licensed to MNOs by region

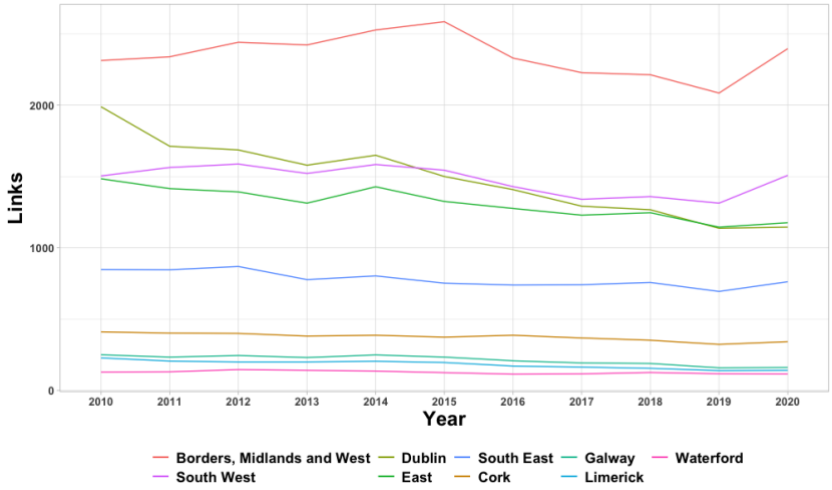
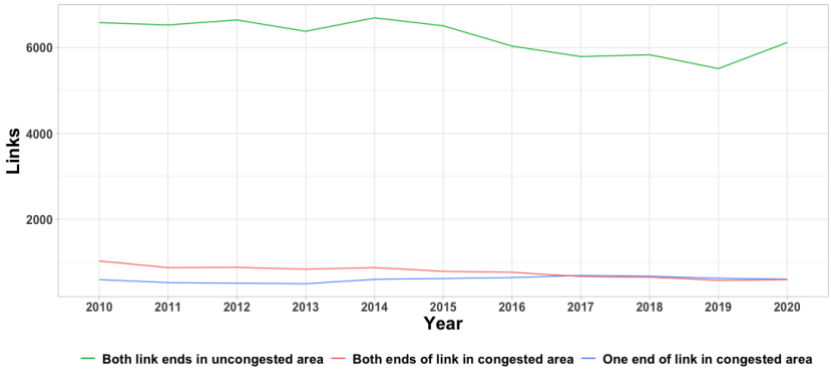
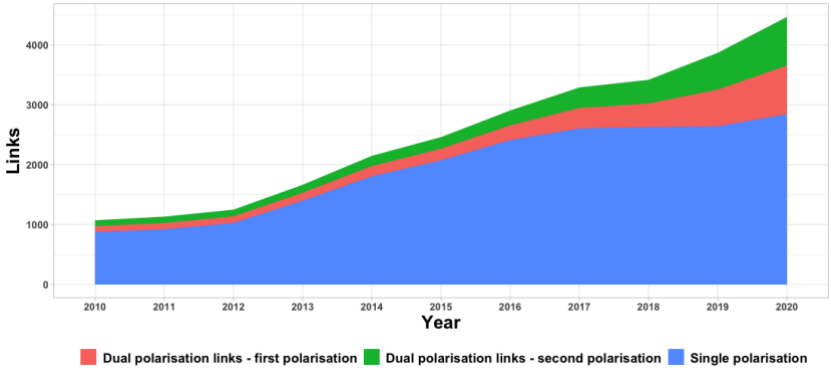


Figure 16: P-P links licensed to MNOs by whether one, both, or neither end in the congested area



C.1.2 FWA operator links

Figure 17: P-P links licensed to FWA operators over time



The graphs in this section show the same information as presented above for MNOs, but in this case look at links licensed to FWA operators. Regarding the total number of links, we see:

- strong growth in number of links as well as use of dual polarisation; and
- growth in number of links used with single polarisation tails off from 2017, suggesting that new links from then are typically used with dual polarisation.

Taken together with the previous analysis, we see that the fall in the total number of links is driven by the MNOs, who operate more links than any other type of user.

For FWA operators' links, the upwards trends are similar in all parts of the country, but until 2020 there were more links in Dublin than any other region, despite the rural regions covering

much larger areas. However, growth has been strongest outside of the congested area.

Figure 18: P-P links licensed to FWA operators by region

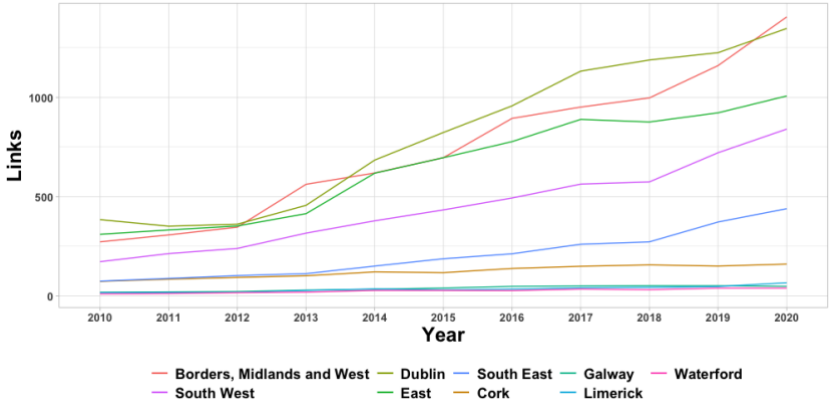
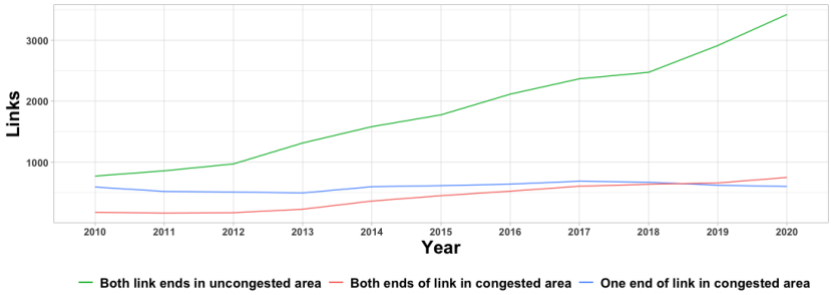
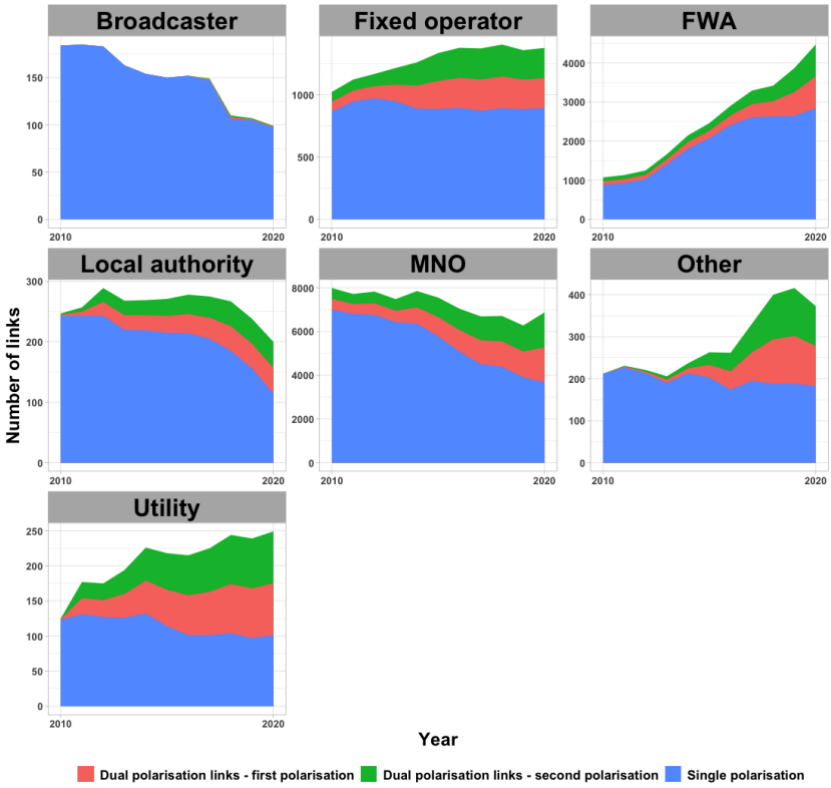


Figure 19: P-P links by whether one, both, or neither end in the congested area



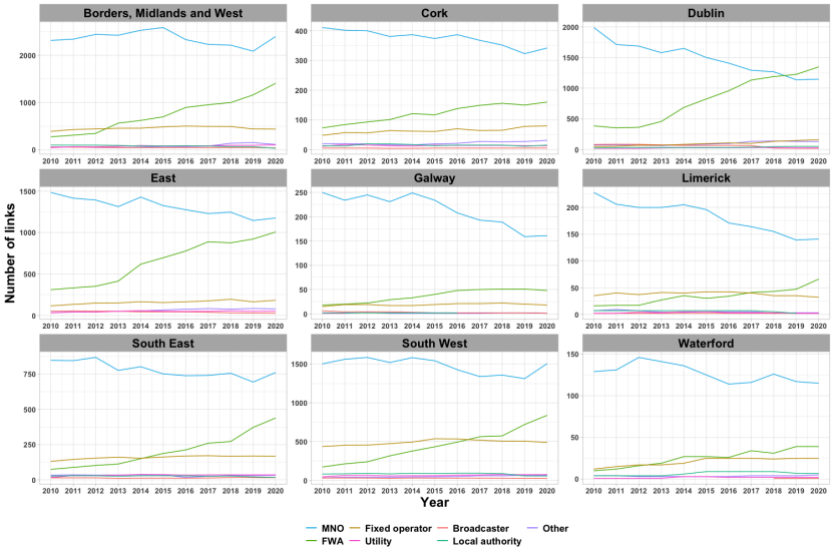
C.1.3 Links by user type

Figure 20: P-P links by user type over time



A significant number of fixed links are licensed to users other than MNOs or FWA operators, so we show trends for further use cases in this section (though we note that the levels of demand are much lower for these). Overall growth seems to be largely driven by demand from FWA operators, but growth in the number of links licensed to fixed wireless operators is offset by the consolidation of fixed links by MNOs. Demand from other users is relatively static, though dual polarisation links have become much more common, and there are differences in the trends between user types (e.g. a fall in local authority and broadcaster links not seen for utilities).

Figure 21: P-P links by user type, by region

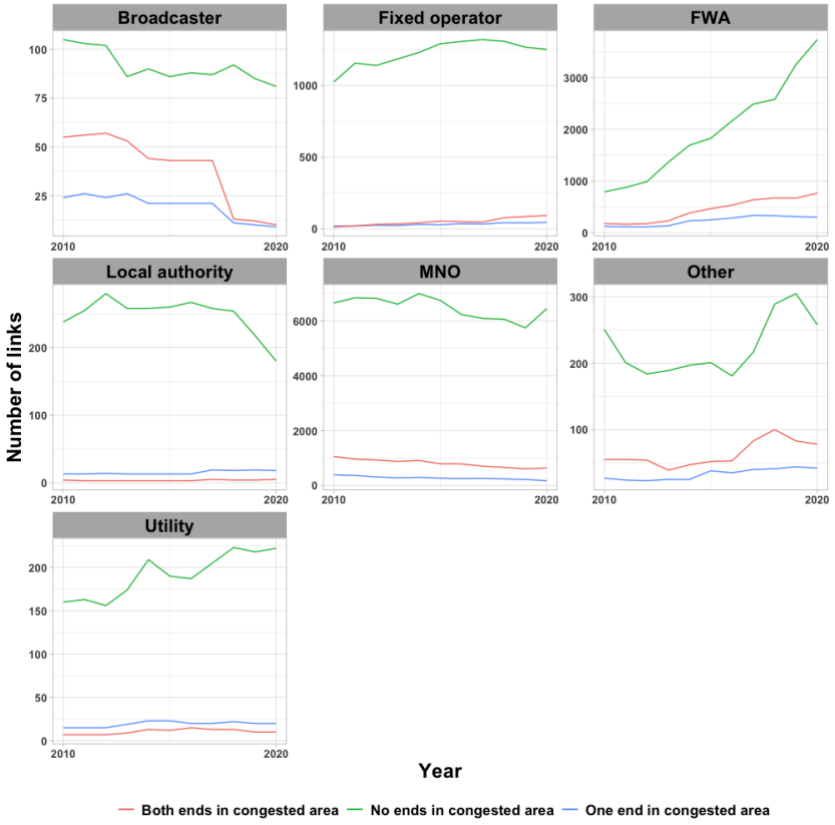


Looking at the user types in each region, we note that:

- the clearest contrast between trends for MNO and FWA operators is in Dublin; and
- no other use case is concentrated in any particular region, other than a significant number of fixed operator links being in the two largest rural regions by area.

Although the number of FWA links is increasing everywhere, the growth in Dublin suggests they may have contributed to the congested bands becoming congested.

Figure 22: P-P links by user type, by whether one, both, or neither end in the congested area



C.2 Bandwidth

In this section we provide further detail on the bandwidth associated with P-P links. Looking at all links in each band, we see that:

- bandwidth growth is indeed driven by deployment of 80 GHz links (mostly over a single polarisation; but
- in the 11 GHz, 13 GHz, and 15 GHz bands, where there is less spectrum available, bandwidth growth is achieved using dual polarisation links.

Figure 23: Spectrum in use and link bandwidth (MHz) by band

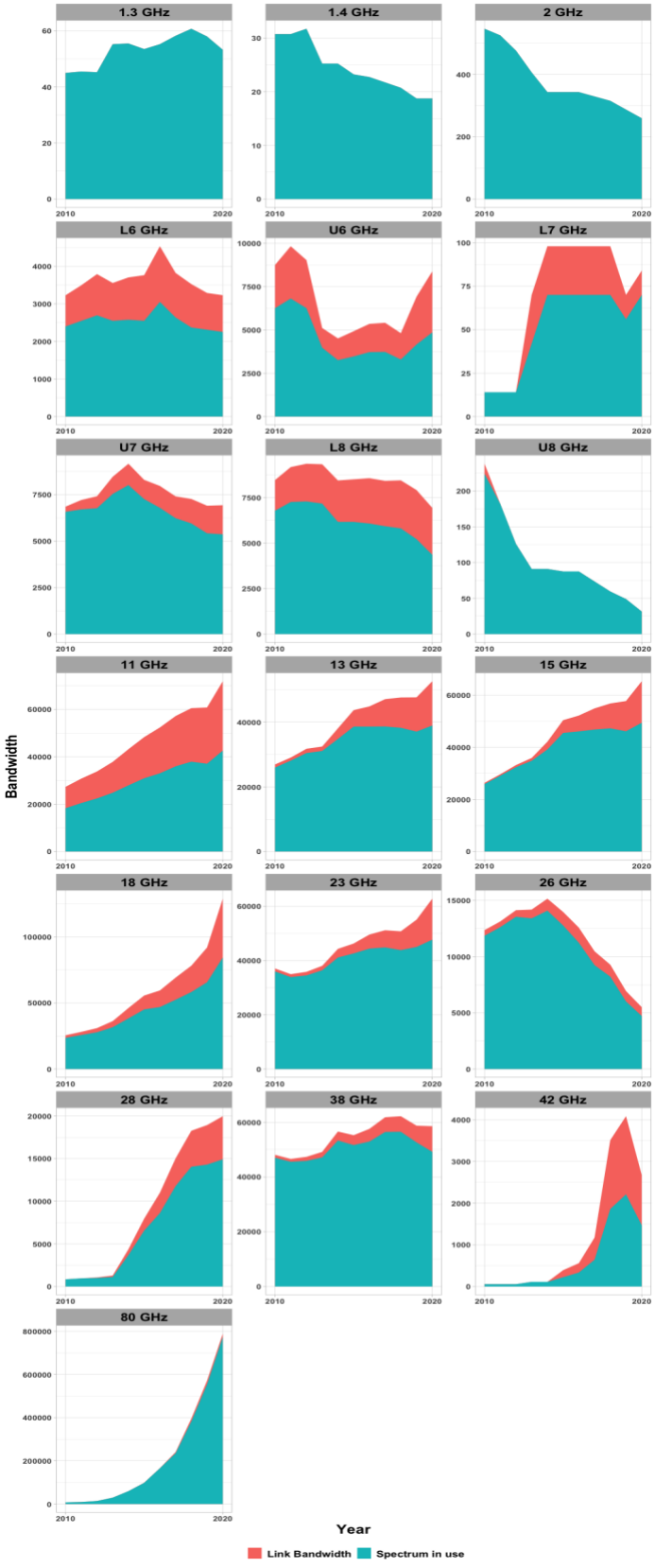


Figure 24: Spectrum in use and link bandwidth (MHz) by region

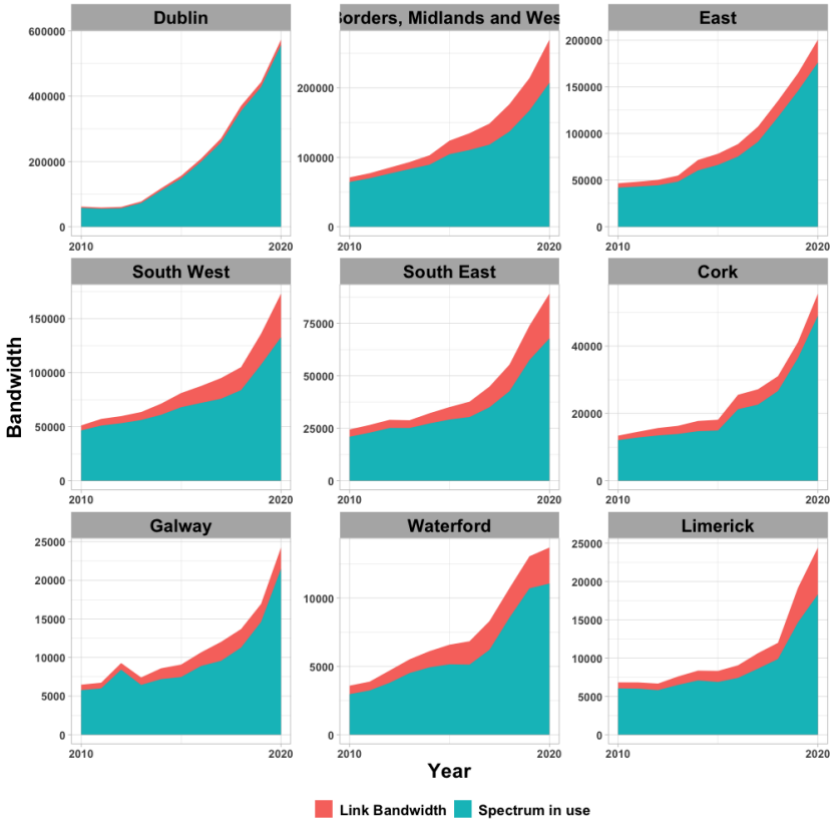
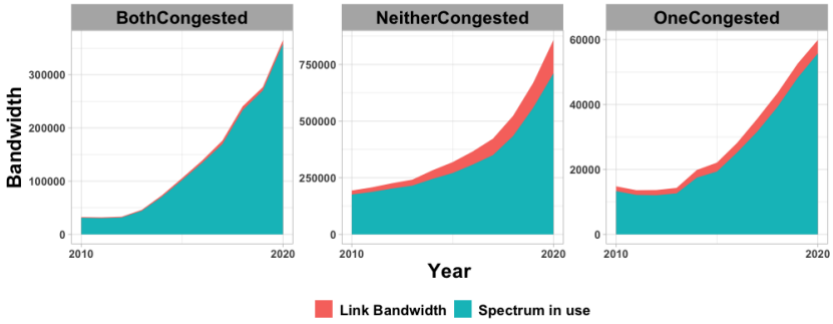


Figure 24 presents the trends in link bandwidth and spectrum in use separately for each region, showing that link bandwidth is growing:

- particularly rapidly in Dublin, and this is driven by use of the 80 GHz band;
- in the rural regions, but relying more on dual polarisation links, because average link lengths are longer in these areas, so lower frequency bands with good propagation characteristics (e.g. 11 – 15 GHz) are popular, and these are often the bands where use of both polarisations is important (e.g. because at most 56 MHz channels are available); and
- although starting from a much lower level, more spectrum is being used in the other cities, particularly in Cork.

Link bandwidth growth (i.e. achieved using dual polarisation rather than new channels) appears to be most significant outside of the congested area, suggesting users are more likely to move up to higher bands with wider channels when there is no spectrum available in the lower band (13 GHz and 15 GHz in this case), which is more likely to be feasible in the city, where path lengths tend to be shorter.

Figure 25: Bandwidth (MHz) by whether one, both, or neither end in the congested area



C.2.1 Bandwidth on MNO links

This section presents bandwidth on links licensed to MNOs across all bands, confirming growth is facilitated by the 1000 MHz channels in the 80 GHz band, and a regional breakdown.

Growth in the congested area, and Dublin generally, is almost entirely in the 80 GHz band, suggesting that users do not need marginal increases in capacity on links from high sites into the city, but rather new, short, much higher bandwidth links.

Figure 26: Total bandwidth (MHz) on MNOs' individually licensed links

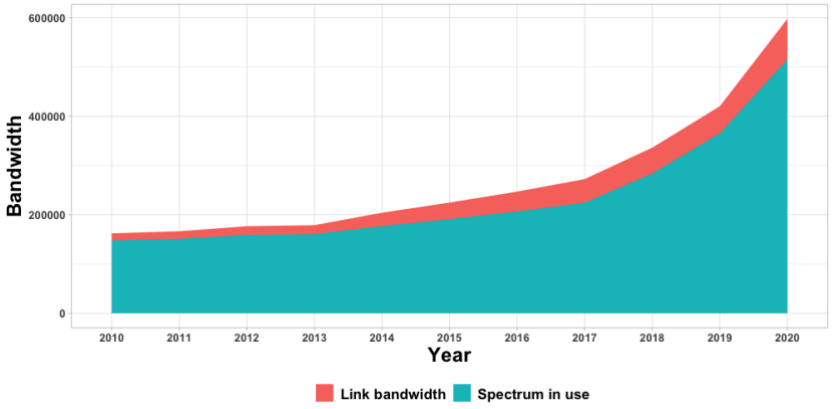


Figure 27: Bandwidth (MHz) on MNO links by region

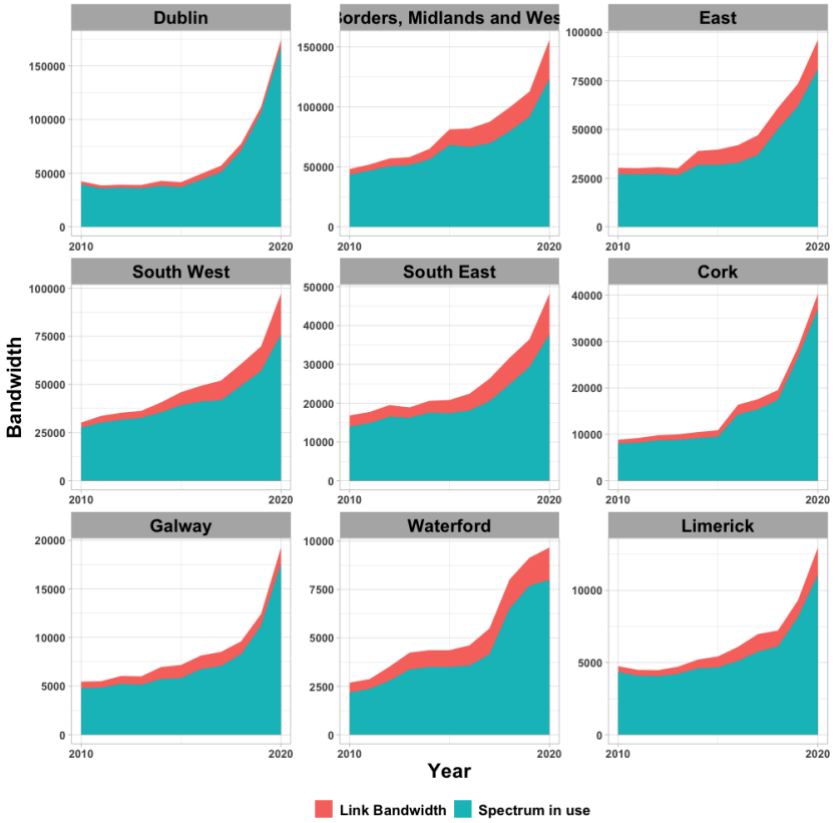
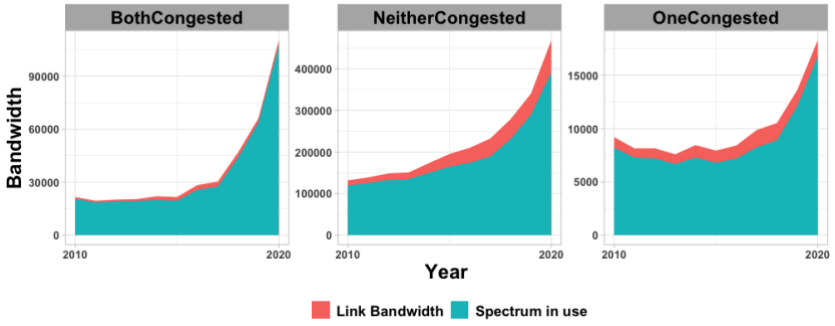
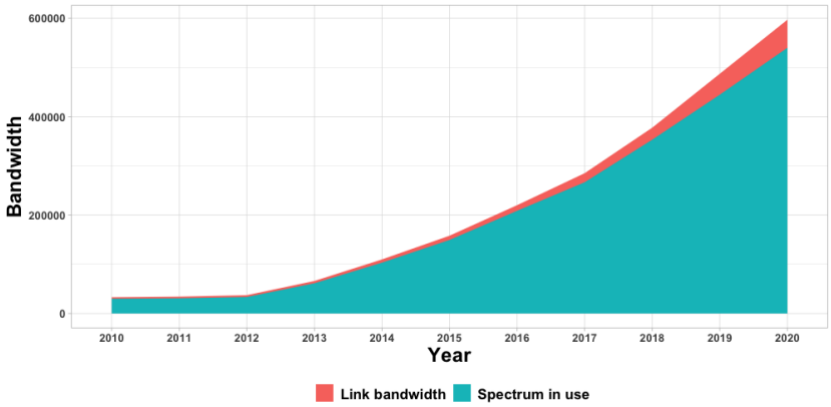


Figure 28: Bandwidth (MHz) on MNO links by whether one, both, or neither end in the congested area



C.2.2 Bandwidth on FWA operator links

Figure 29: Total bandwidth (MHz) on links licensed to FWA operator



The timing of the trends appears slightly different for FWA links than for MNOs. MNOs demand had accelerated more recently, whereas that from FWA operators has been increasing at a similar rate for a longer time.

Figure 30: Bandwidth (MHz) on FWA operator links by region

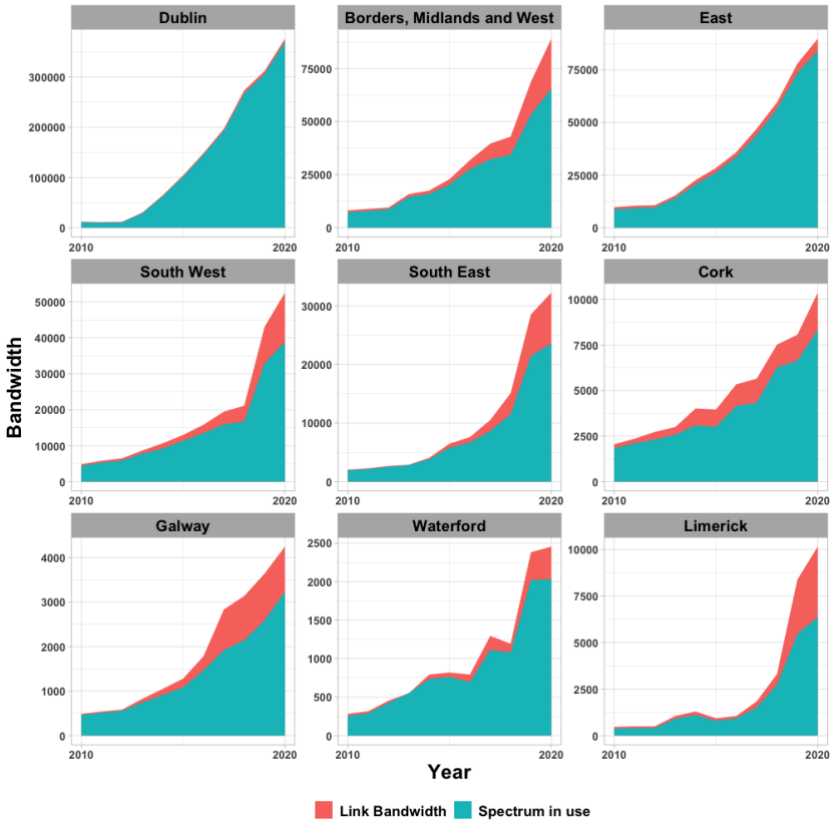
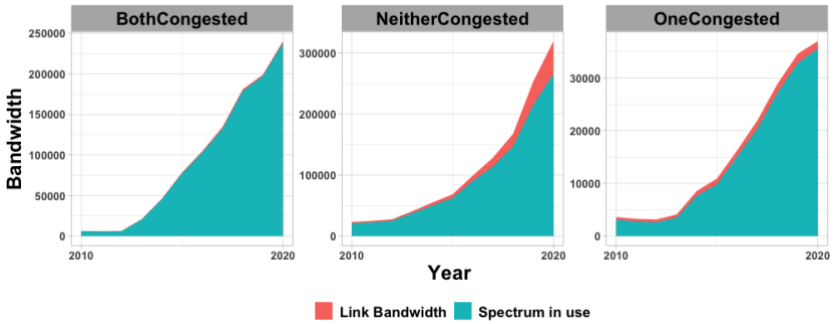
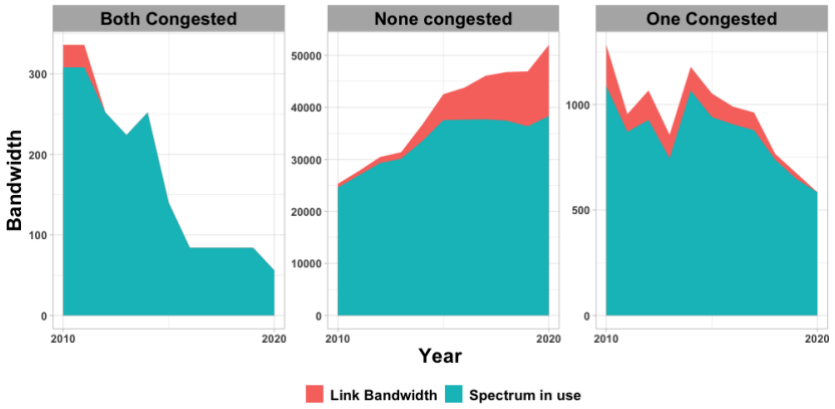


Figure 31: Bandwidth (MHz) on FWA operator links by whether one, both, or neither end in the congested area



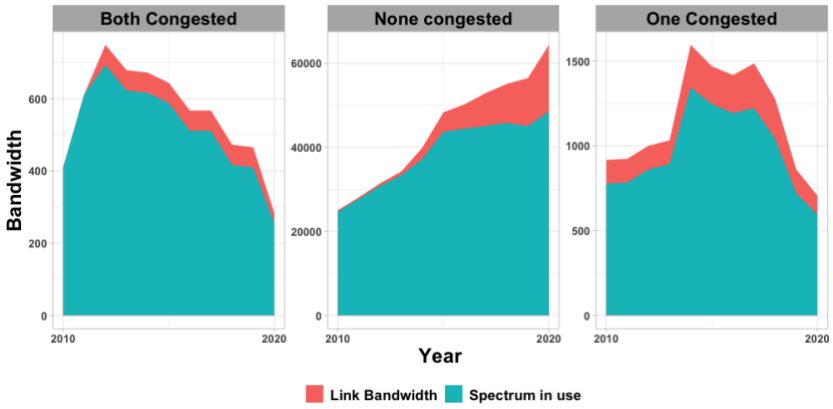
C.3 Spectrum in use in the 13 GHz and 15 GHz bands

Figure 32: Bandwidth (MHz) on 13 GHz links by whether one, both, or neither end in the congested area



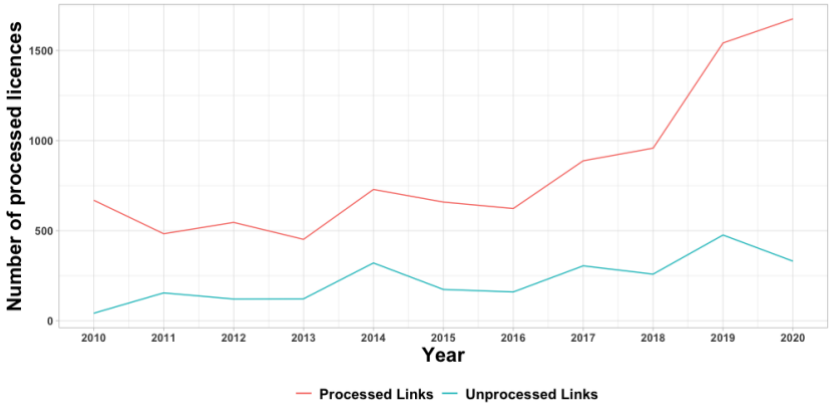
The two graphs in this section show the trends in bandwidth on link in the 13 GHz and 15 GHz bands in the congested area, that is, where no new applications are currently being accepted in these two bands, compared to the rest of the country. In both cases, the spectrum in use is falling on links with one or both ends in the congested area. This is consistent with our concern that spectrum may be left inefficiently unused if the bands remain closed.

Figure 33: Bandwidth (MHz) on 15 GHz links by whether one, both, or neither end in the congested area



C.4 Unprocessed applications

Figure 34: Processed and unprocessed applications over time



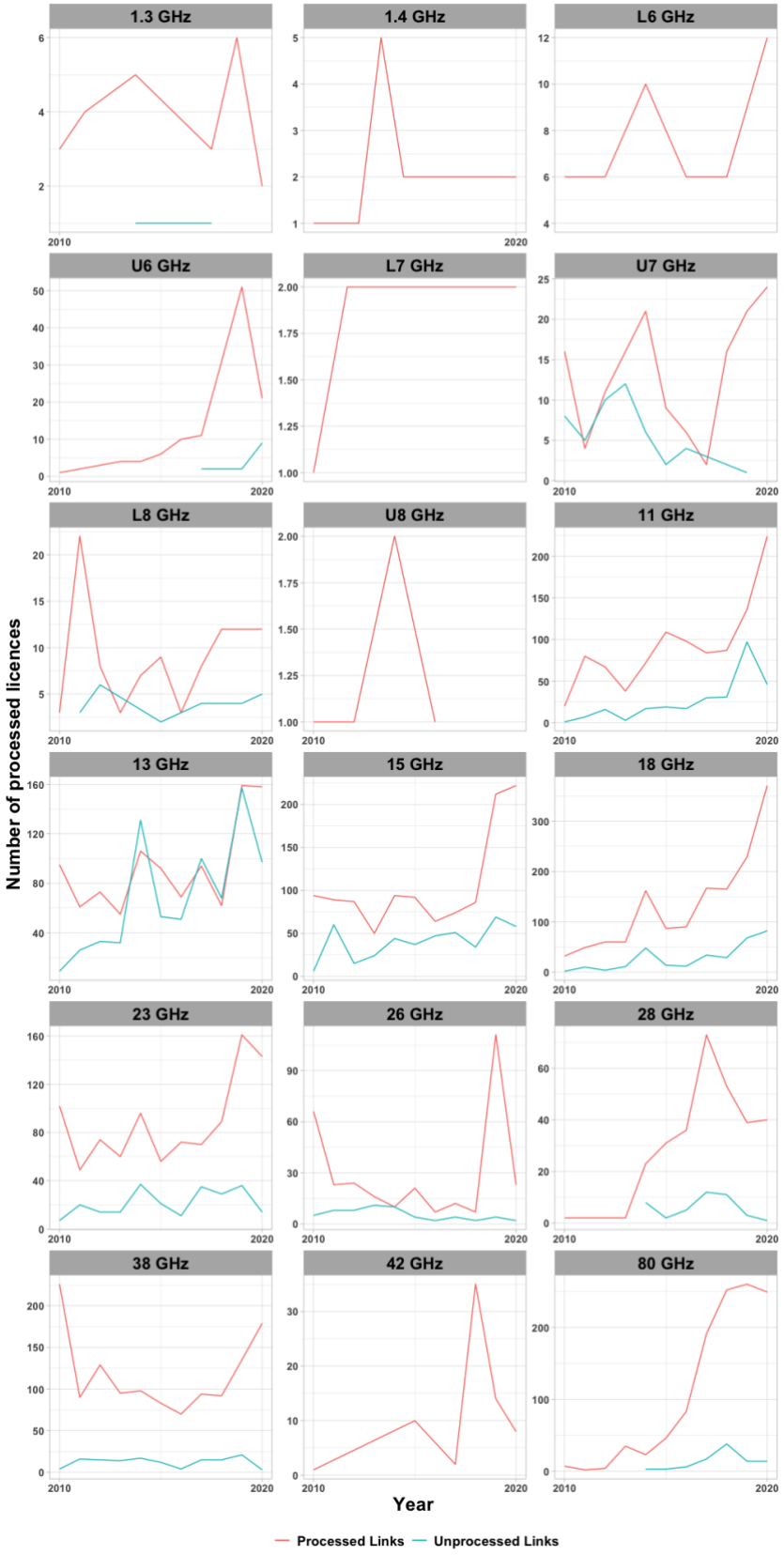
We also have data on the applications that were not processed in each year (for the graphs in this section, an 'application' is for a single link, even if multiple links were requested at the same time). Where we are concerned about congestion, demand for fixed links is not only the number of links in use, but also the number of links operators wanted to install, but were not able to because they could not find a channel. However, there are other reasons for an application not to be processed, such as if the applicant cancelled it or it did not meet the technical requirements as set out in the guidelines. This graph plots the number of new live licences against the number of unprocessed applications in each year. We note that:

- some roughly constant proportion of applications could be expected to go unprocessed, due to e.g. errors in applications;

- we must be cautious with interpreting unprocessed links as a measure of demand, as users may submit multiple applications, but ultimately only want one channel;
- we might expect unprocessed links to increase when it is harder to find a channel due to congestion (unless operators know there is little hope of them finding a channel and do not apply); however,
- processed links have increased considerably without a corresponding increase in unprocessed links, suggesting that there is no aggregate scarcity.

Figure 35 then presents unprocessed links by band. Here, we do see some evidence of the number of unprocessed links increasing with the number of processed links in the 11 – 23 GHz bands, where scarcity may be an issue, but there is a large number of new links in the 80 GHz band with few unprocessed links, because there is ample spectrum available in that band. After the recent amendment to the information policy in the application stage, we may expect fewer unprocessed applications in the future.

Figure 35: Processed and unprocessed applications by band



C.4.1 Unprocessed applications from MNOs

The following graphs present the aggregate and by band trends in processed and unprocessed applications from MNOs.

In this case, there are relatively few unprocessed links, because new applications are concentrated in the 80 GHz band where ample spectrum is available.

Figure 36: Processed and unprocessed applications from MNOs

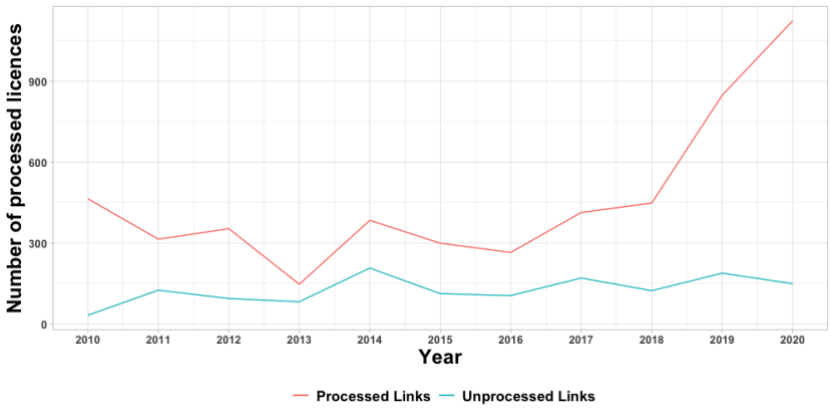
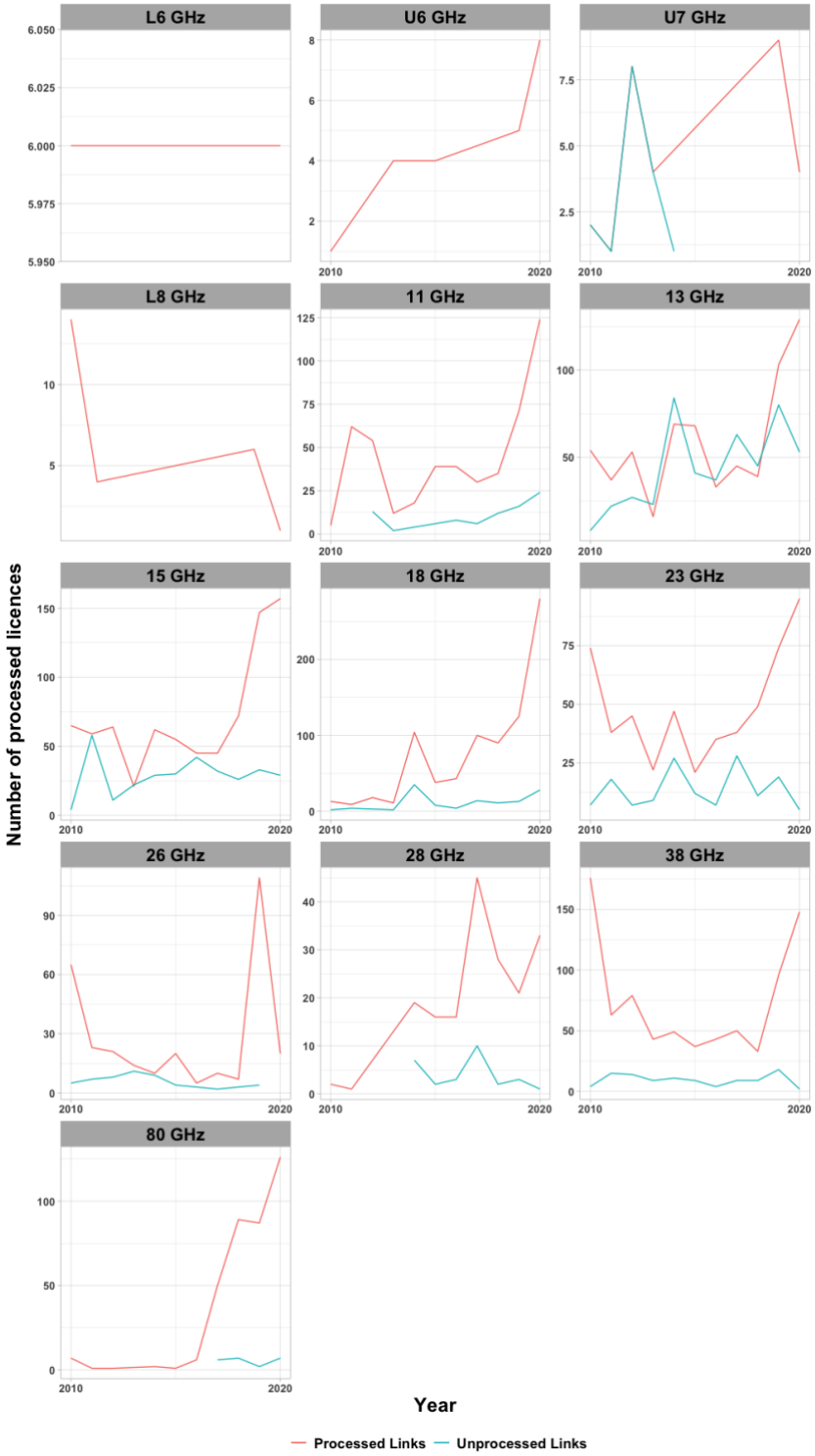


Figure 37: Processed and unprocessed applications from MNOs by band



C.4.2 Unprocessed applications from FWA operators

The trends are similar for FWA operators, but with more unprocessed links in some bands (e.g. 18 GHz) compared to the

MNOs, possibly due to FWA operators need to choose bands on a customer by customer basis, rather than congestion (which we would expect to be the same for users if they used similar paths).

Figure 38: Processed and unprocessed applications from FWA operators

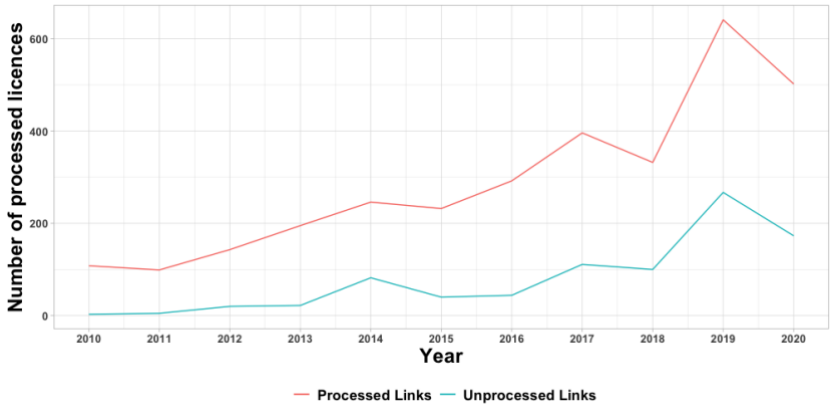
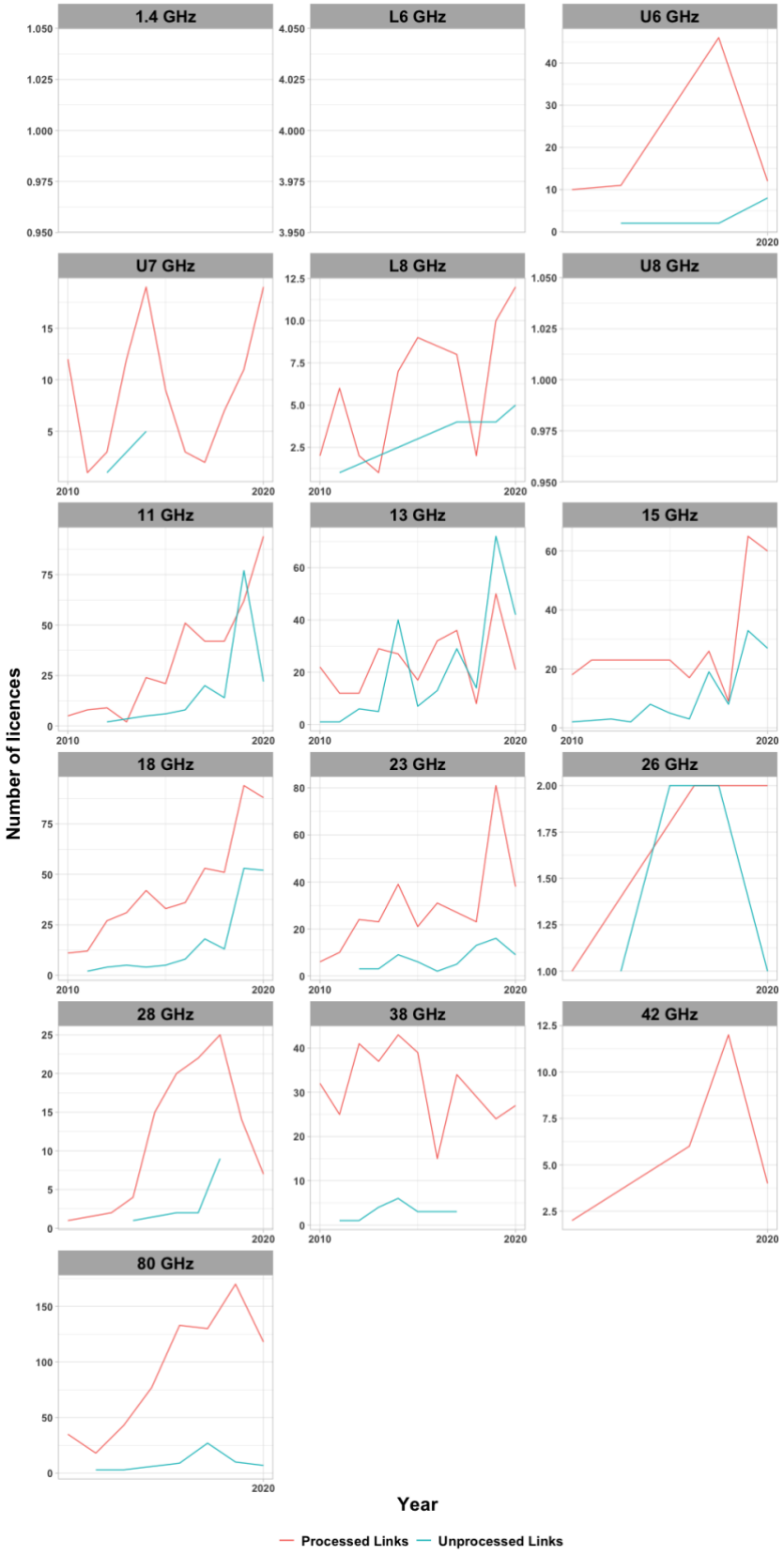
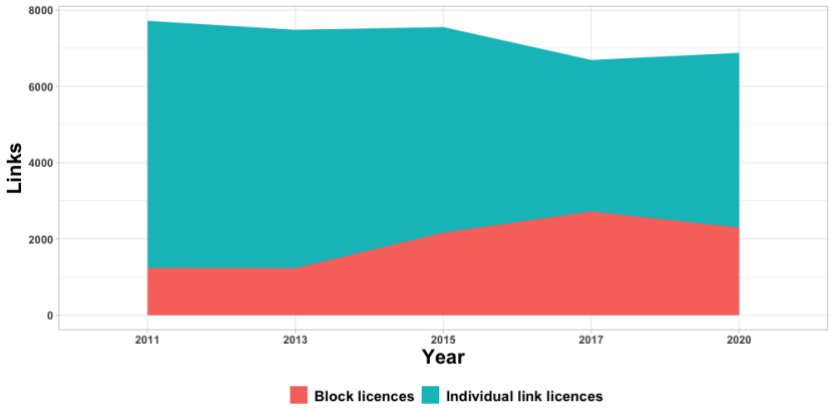


Figure 39: Processed and unprocessed applications from FWA operators by band



C.5 Block licences in the 26 GHz band

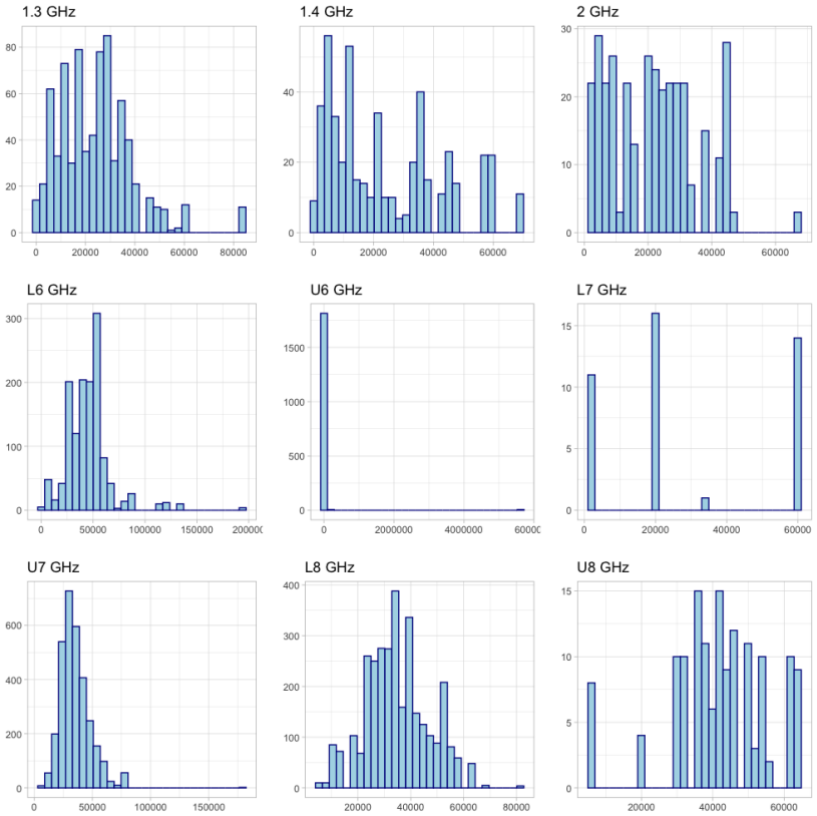
Figure 40: All MNO links, block and individually licensed



In Section 2, we present a conservative estimate of the number of links deployed on block licenses and individually licensed MNO links in the 26 GHz band. Here, we include individually licensed MNO links across all bands, and again the graph this suggests that demand from MNOs is not falling in the way suggested by looking at the number of MNO links alone, but instead see a significant proportion of MNOs fixed links being operated under block licences. We also note that each MNO effectively has access to 112 MHz channels on its block licence, and that these graphs may underestimate the extent of block licence use.

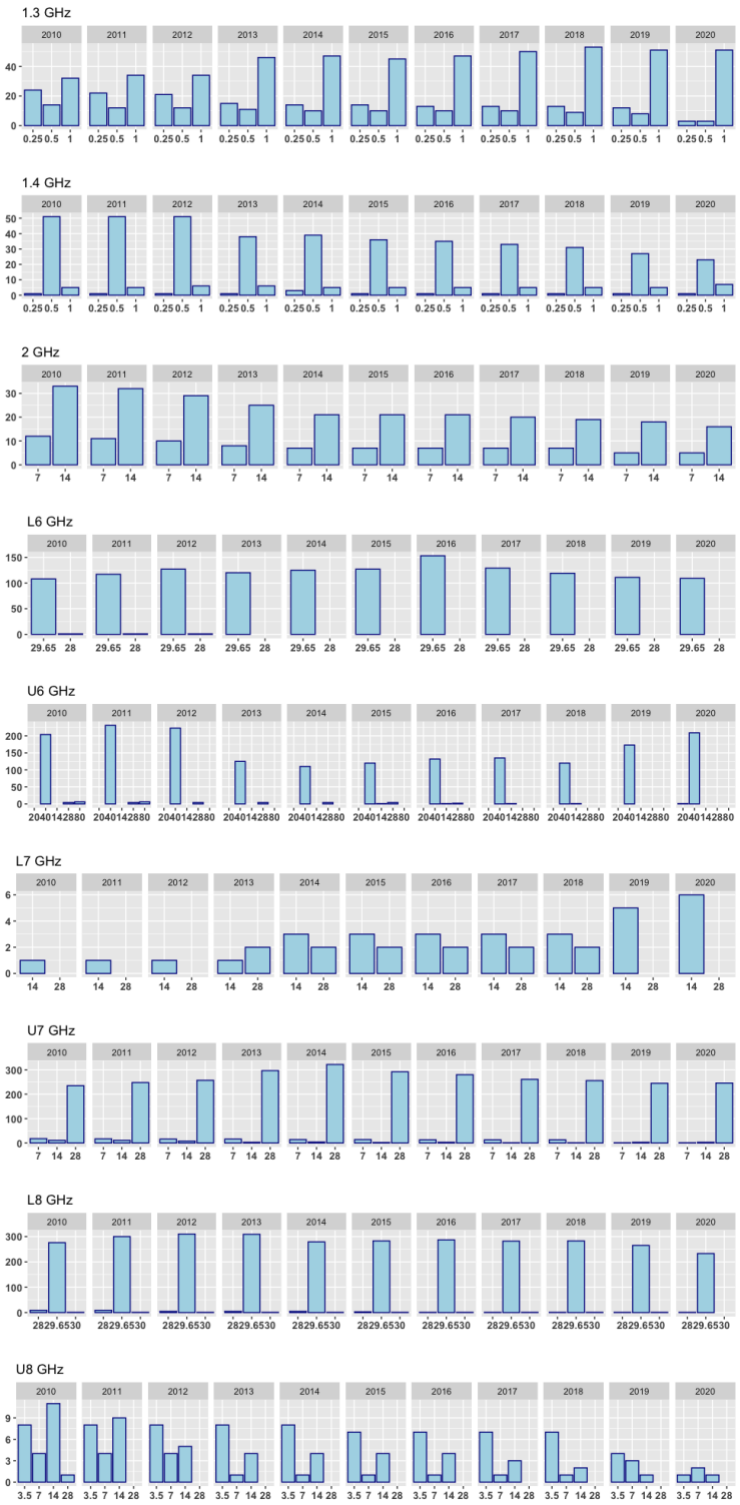
C.6 Link length

Figure 41: Distribution of link lengths (in metres) by band



C.7 Channel widths

Figure 42: Number of links of each channel width (MHz), by band, over time



C.8 Fragmentation

In Section 2, we explained that there is potentially an issue of fragmentation in some bands, which would prevent spectrum being used efficiently. This could occur if the channel widths demanded by operators increase and, while there is sufficient unused spectrum available to accommodate a new larger channel, the organisation in of the existing links in the band preclude the new higher capacity link from being installed.

As a simple example, suppose in a given hypothetical band there is a total of 112 MHz of spectrum that could be assigned for individual fixed links, and that on a given path two licences are already allocated with a channel width of 28 MHz each. If these licences are for adjacent channels at either end of the band (i.e. if they are packed "neatly" into the band), whether adjacent at either end, or one each at opposite ends of the band, it would be possible to fit in either two additional 28 MHz licences or a single 56 MHz licence over the same route. If, on the other hand, they are not in adjacent channels or are positioned next to one another but in the middle of the band, the remaining spectrum available for new links would be in two non-contiguous 28 MHz blocks. It would still be possible to fit in two new 28 MHz licences, but ComReg might not be able to grant a single polarisation 56 MHz licence, even though there is sufficient spectrum free in total. In cases like this, we refer to the band as 'fragmented'.

Fragmentation is not an issue if the large majority of users all want the same channel size and spectrum is offered in that channel size. In this case, any gaps would be useable by all parties, even if they offer only single channels. However, the majority of the fixed links bands are offered with a range of channel widths, with currently allocated licences spread across the range. While this is in some ways supportive of efficient spectrum use (operators with limited bandwidth requirements do not need to acquire larger channels that are then partially unused), it does create potential fragmentation issues where the unallocated frequencies are not in sufficiently large contiguous blocks to allow access to greater bandwidths (even if there is enough free spectrum overall to do so).

Naturally this is more likely to be an issue for users looking to access larger channels, which will be less likely to fit into the unallocated spectrum where this is broken up into several blocks. There is clear evidence from the data of growth in demand for larger contiguous bandwidth (i.e. with demand

shifting away from the smaller channels used historically and an increase in used of the wider channels e.g. 56 MHz and even moving up to 112 MHz). This creates a risk of inefficiency if currently unused spectrum is fragmented and cannot be utilised to its full potential by larger bandwidth users.

We have run some analysis on the individual links data to assess the extent to which fragmentation is an issue. Measuring fragmentation cannot realistically be completed to a high degree of accuracy, given the complexity of the interference analysis that would need to be required and the fact that this would need to be conducted on an individual route basis. We have therefore used a simplified method to provide a pessimistic overview that would overestimate the degree of fragmentation, noting that if this does not highlight any problems then we could be reasonably confident that no issue would be apparent with a more rigorous analysis. In particular, for a given band:

- We first split Ireland into a number of grid squares, with the size of the squares based on the average link length for the band currently operated over.
- For a given grid square, we then look at all of the links with at least one end in the square and consider the frequencies used over those links as "used" for that square (we recognise that this does not fully represent the possibility of using the same frequencies over different routes within the square, but simplification along these lines is necessary for us to feasibly measure whether a frequency range is free or used within a particular area).
- We then have a band plan for each square that splits the band into blocks of used and unused spectrum within the square.
- For a given grid square and channel width, we can then compare the number of channels that could be assigned given the band plan with the number of channels that could be assigned if all of the unused spectrum formed a contiguous block. The more these numbers differ, the greater the impact fragmentation could be considered to have on the potential for assigning channels of the given size.
- For a given grid square s, let b_s be the number of channels that could be assigned under the band plan as it is, and let c_s be the number of channels that could be assigned if all of the unused spectrum

formed a contiguous block. We create a fragmentation metric, f_s, where $f_s = 1 - (b_s/c_s)$.

- Where $f_s = 0$ there is no issue of fragmentation i.e. the unused spectrum is available in block sizes that are all equal to a multiple of the given channel width
- Where $f_s > 0$, the way in which the unused spectrum is split into multiple blocks is preventing the assignment of one or more licences at the given channel size.

We have represented the results of this exercise in the form of heat maps that are colour coded to indicate the severity of the fragmentation issue. The lighter the square, the greater the fragmentation metric. Note that we have focussed our analysis on the larger channels available within each band (where we expect the problem to be more significant) and one step beyond to indicate likely future issues as demand for greater bandwidth increases. The heatmaps for each band are presented below.

We can see clearly that fragmentation becomes more of an issue as we move up into larger channel widths. With 28 MHz channels there is some impact of fragmentation in some areas, but no issue in the majority of the country. The number of "problem areas" increases as we assess the options for assigning 56 MHz channels, and for 112 MHz channels fragmentation appears to have an impact in a large proportion of Ireland.

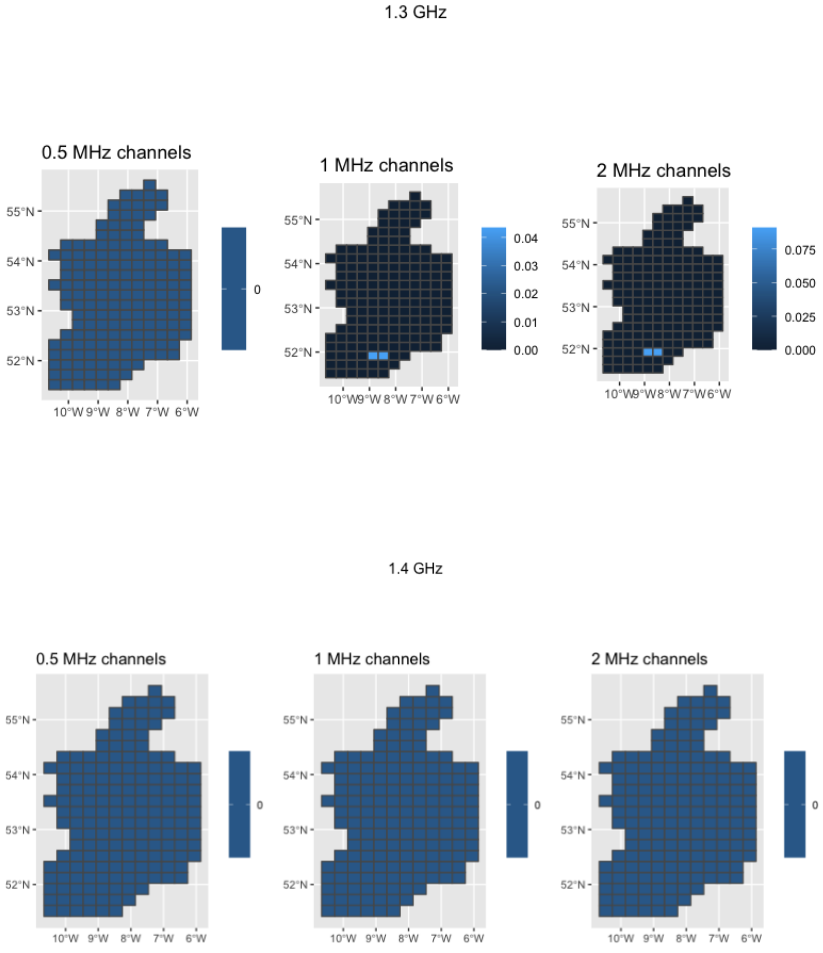
It is worth noting that the interpretation of this analysis does need to be taken in the context of the individual band. It is not surprising, for example, that fragmentation appears much more prevalent in the 13 GHz and 15 GHz bands where there is limited spectrum available relative to some of the other bands (and so it does not take much to break up the available frequencies into blocks that cannot accommodate larger channels).

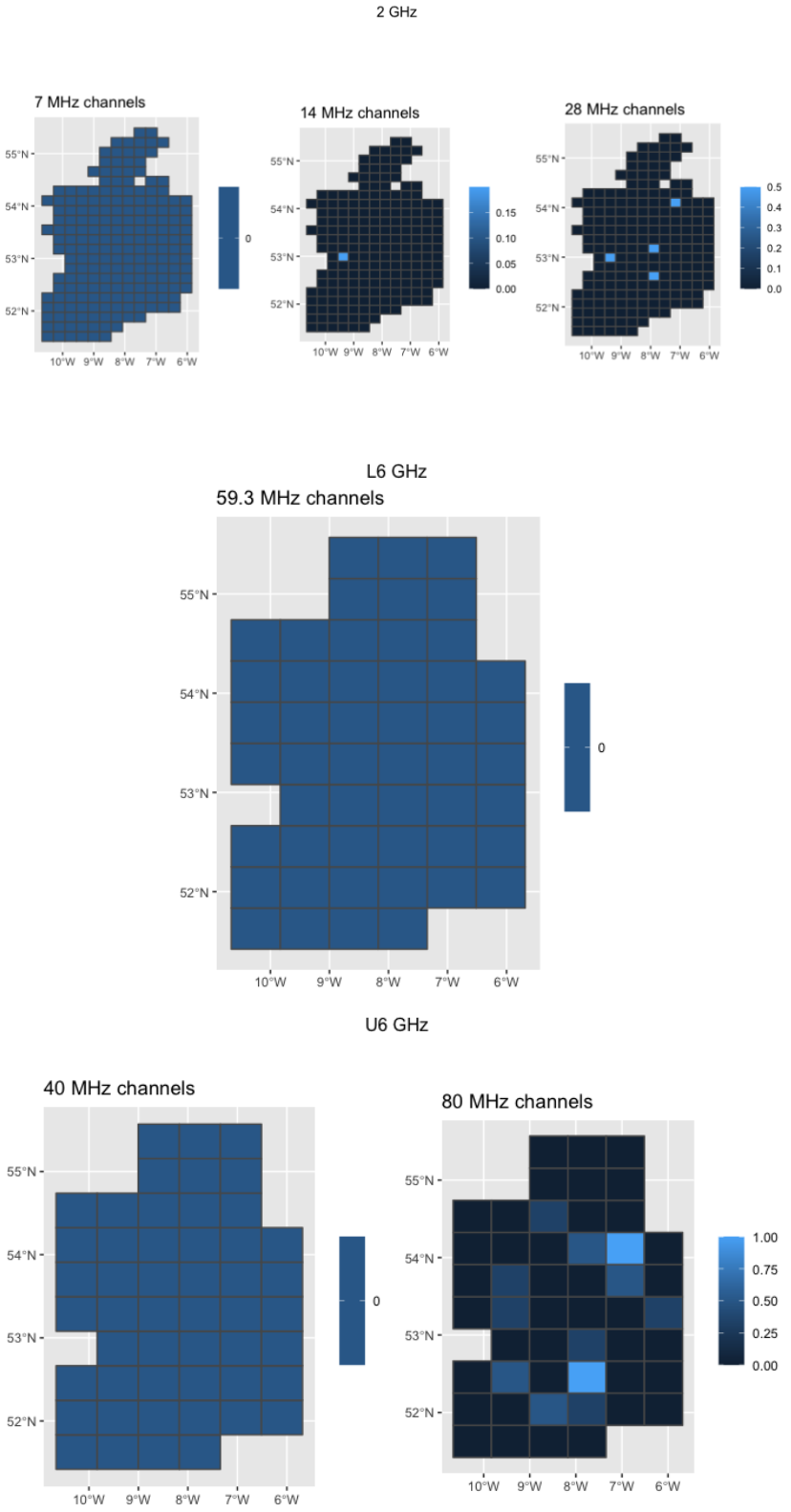
In the 18 GHz to 28 GHz bands there appears to be some impact, but to a lesser extent and with the areas affected largely in the region of Dublin and Cork. The figure below shows the results for the 23 GHz band. In the 38 GHz and 42 GHz bands fragmentation does not seem to be an issue.

We should also highlight that the analysis likely overplays the problem, for the reasons discussed above regarding the need to simplify the measure of whether a frequency range is used in a given area. In any case, where fragmentation is identified as a

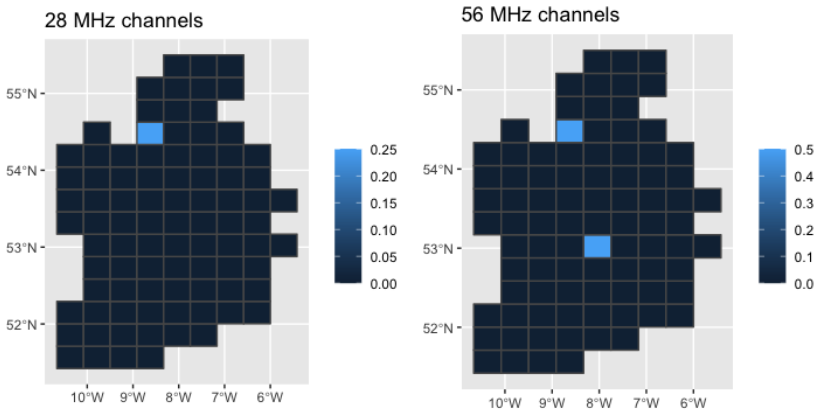
potential issue, we anticipate that there is very limited scope for ComReg to address this under the current individual link licensing regime. Therefore, we think it is worth being aware of the theoretical issue, and operators may comment on whether it is has been an issue in practice, but we do not think it requires action from ComReg. In any case, our analysis has overstated the issue currently (i.e. because of the extremely pessimistic definition of interference), and use of XPIC configurations and carrier aggregation equipment to combine non-adjacent channels would alleviate the problem, particularly in the longer term as equipment is naturally swapped out.

Figure 43: Fragmentation by band

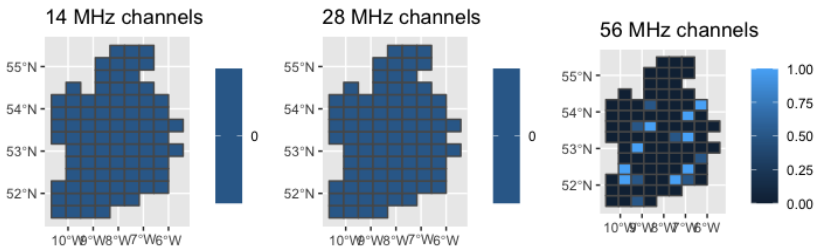



2 GHz
7 MHz channels
14 MHz channels
28 MHz channels
55°N
54°N
53°N
52°N
10°W 9°W 8°W 7°W 6°W
0
0.15
0.10
0.05
0.00
0.5
0.4
0.3
0.2
0.1
0.0
L6 GHz
59.3 MHz channels
U6 GHz
40 MHz channels
80 MHz channels
1.00
0.75
0.50
0.25
0.00

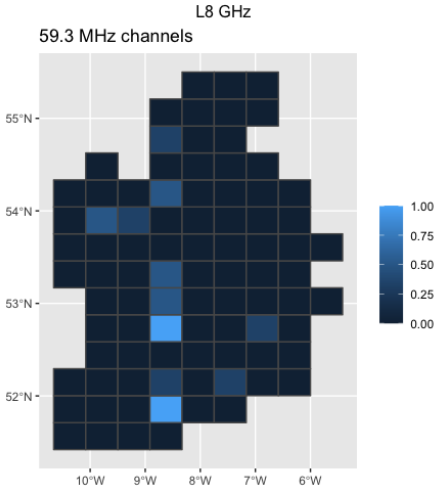
L7 GHz



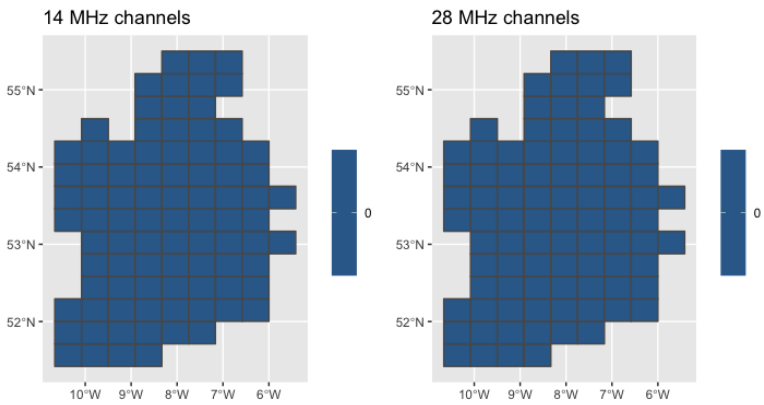
U7 GHz



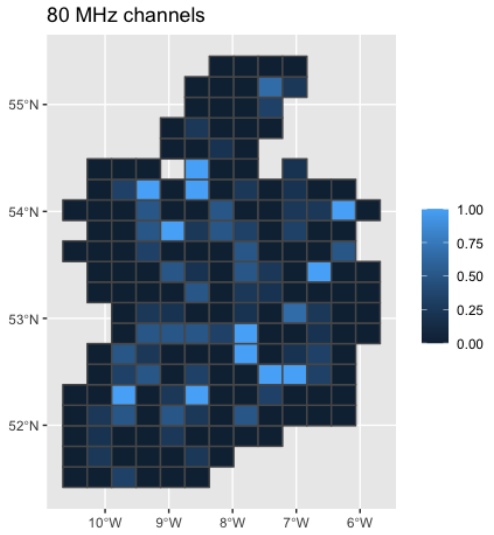
L8 GHz



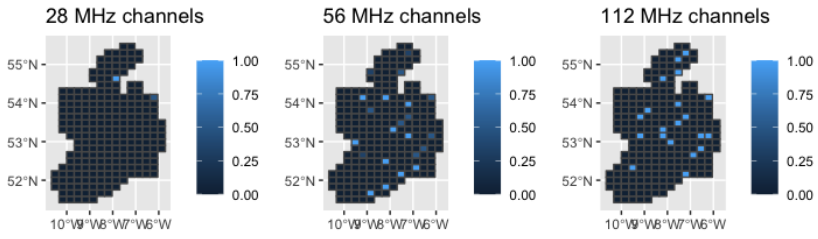
U8 GHz



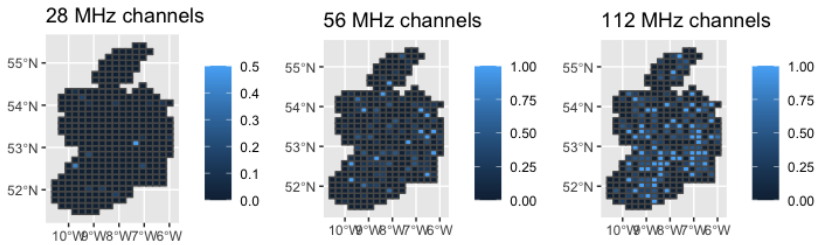
11 GHz



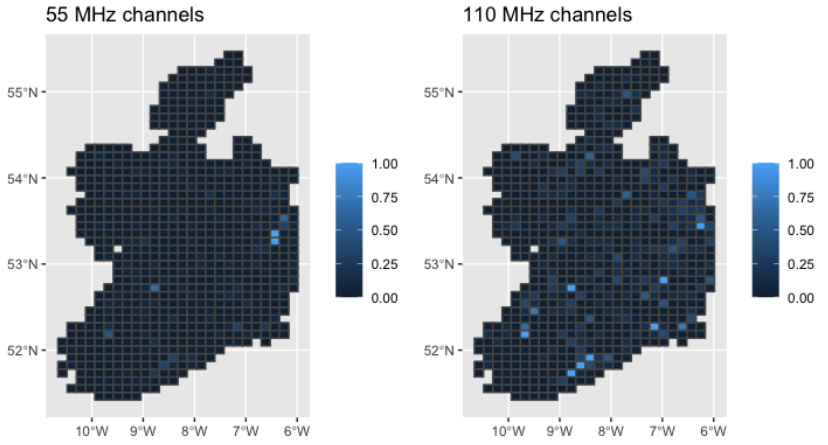
13 GHz



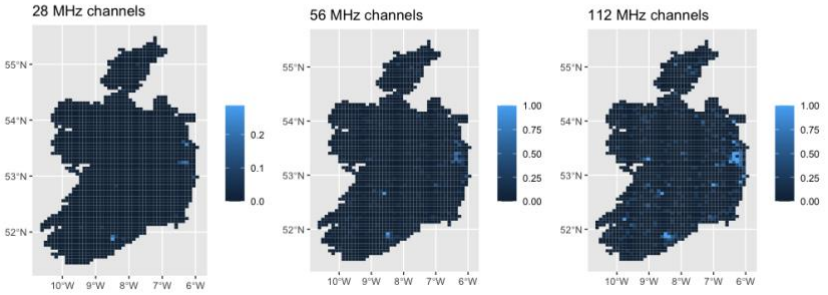
15 GHz



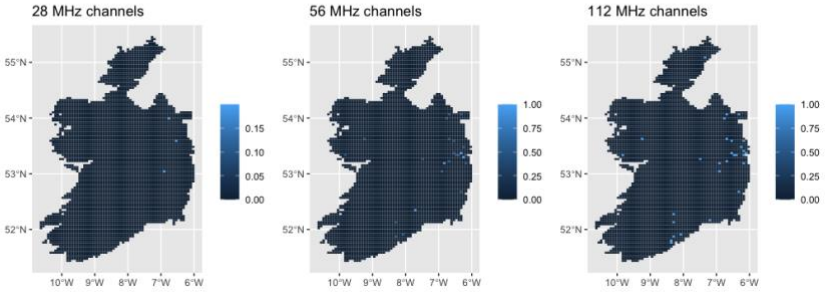
18 GHz



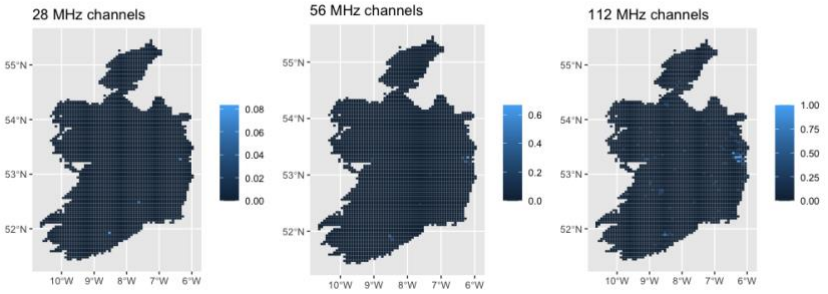
23 GHz



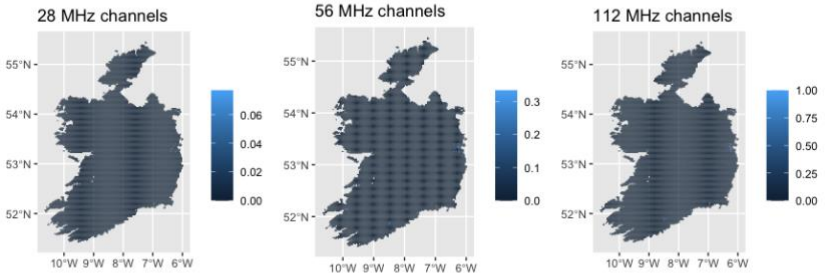
26 GHz



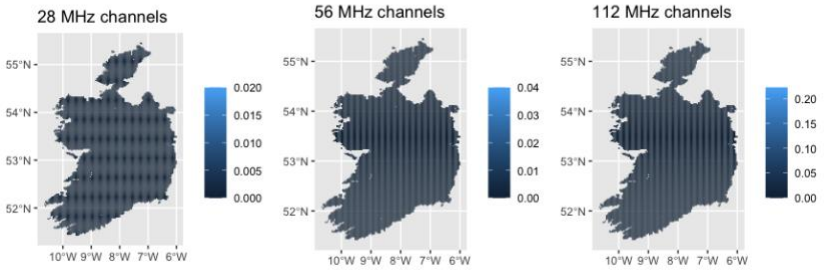
28 GHz



38 GHz



42 GHz


28 MHz channels
56 MHz channels
112 MHz channels
55°N
54°N
53°N
52°N
10°W 9°W 8°W 7°W 6°W
0.020
0.015
0.010
0.005
0.000
0.04
0.03
0.02
0.01
0.00
0.20
0.15
0.10
0.05
0.00

80 GHz


500 MHz channels
750 MHz channels
1000 MHz channels
1250 MHz channels
1500 MHz channels
1750 MHz channels
2000 MHz channels
4000 MHz channels
55°N
54°N
53°N
52°N
10°W 9°W 8°W 7°W 6°W
1.00
0.75
0.50
0.25
0.00