An Coimisiún um
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Commission for
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Meeting Consumers' Connectivity Needs

a report from Frontier Economics

Consultant Report

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MEETING CONSUMERS' CONNECTIVITY NEEDS

A report for ComReg:

November 2018

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EXECUTIVE SUMMARY

Connectivity describes the ability of users and their devices to connect and communicate with each other across different networks. Connectivity involves various forms of communication but primarily includes sending and receiving data, voice calls and SMS messages. Widespread and deep social and economic changes have been enabled by investments in telecommunications networks, devices, new software and other new services to support connectivity. The widespread adoption of data connectivity across consumer devices and business processes has changed how we consume, purchase and communicate.

Stakeholders in Ireland are doing much already to improve the connectivity experience, underpinned by the rollout of fixed and mobile networks, and the future rollout of the National Broadband Plan (NBP) in rural areas unserved by high speed broadband which aims to provide access to a modern and reliable fixed broadband network, capable of supporting current and future generations. Crucially, the NBP also has other important benefits including increased access to fibre backhaul in rural areas reducing the cost of providing other connectivity services. It will also support in building use of Wi-Fi on mobile devices (such as Native Wi-Fi voice calling[1]). However, connectivity involves multiple different networks and stakeholders all of which have a role in using available resources more efficiently.

ComReg commissioned Frontier to provide a report which illustrates and summarises the linkages between the activities of various stakeholders (government, regulators, operators, consumers, equipment manufacturers etc.) which have the potential to meet and improve the connectivity experience of consumers in Ireland and thereby support the productive capacity of the Irish economy. In that regard, this report provides an overview of where consumer connectivity stands in Ireland, the challenges involved in providing for further connectivity and the actions that stakeholders can take to optimise levels of connectivity on different networks across Ireland.

While this report is primarily focused on the connectivity experience for consumers, it should complement government plans such as Project 2040 and the National Development Plan 2018-2027 where the digital connectivity requirements encompassing broader sectors of the economy are required.

The remainder of the Executive Summary and report is divided into six sections.

- An assessment of demand for connectivity in Ireland.
- An assessment of consumers' needs and Quality of Service issues.
- The challenges Ireland faces in providing connectivity.
- The costs of extensive high speed mobile connectivity.

[1] Native Wi-Fi is a service that can be provided by operators that makes it possible for consumers to make/receive phone calls and text messages from their native Wi-Fi enabled mobile phone, where mobile coverage is not sufficient, by using an existing Wi-Fi network. Native Wi-Fi consumers can use enabled phones and existing mobile phone number to connect via Wi-Fi to the operator-provided voice service for a higher-quality calling. In time, NBP should significantly expand access to high speed broadband in rural areas whereby users would have the possibility to seamlessly make and receive voice calls regardless of building penetration and other limiting factors.

- The role of the National Broadband Plan ("NBP) in extending connectivity.
- The actions stakeholders can take to improve connectivity.

Demand for connectivity in Ireland is growing

Summary of key points
➢ Connectivity is supplied via a number of different networks (fixed and mobile).
➢ Demand for voice calls has remained constant, demand for data connectivity has increased significantly.
➢ 90% of all data downloads are currently made on fixed networks.
➢ Mobile data forecast to increase four fold in next five years.

Connectivity is supplied via a number of different telecommunications networks (fixed and mobile) which can substitute and complement each other depending on the specific use or application. While different networks all have different characteristics (and costs), they all support the transmission of data which enables the countless digital applications on which we now rely on a daily basis.

While demand for voice calls has remained relatively constant, demand for data and high speed data connectivity has increased significantly. In the last three years demand for data (fixed and mobile) has doubled and nearly 90% of all data downloads are made on fixed networks. Ireland also has relatively higher data use (measured on a per capita basis) than comparator countries on both fixed and mobile networks and data use will continue to grow. For example, the trend towards increasing consumption of VoD content means that, gradually, content that would previously be watched on traditional terrestrial or satellite TV networks is instead viewed on fixed or mobile networks.

Consumer demand for connectivity is derived from the wide range of apps and services that rely on data. Consumers expect to be able to roam seamlessly across different networks. Consumers also require connectivity where we live, work, travel and spend leisure time. A recent publication commissioned by ComReg[2] highlights the growing demand for mobile connectivity. It estimated that **mobile data demand is likely to increase by four times over the next five years**.

Mobile data to quadruple in five years

[2] "Mobile Data Traffic Forecast in Ireland" – ComReg Document 18/35.

Consumer's needs and quality of service issues

Summary of key points
➢ Around four out of five consumers report satisfaction with their connectivity experience.
➢ Indoor connectivity is the main connectivity issue reported by mobile consumers. Native Wi-Fi and mobile repeaters are likely to be the most effective solutions.
➢ Rural consumers experience higher rates of connectivity issues.
➢ Newer OTT ('Over The Top') technologies are supplementing consumer usage of Voice and SMS.

The connectivity requirements of consumers and businesses are currently met by a variety of technologies and networks. Connectivity to support most mass market applications requires connectivity that typically:

- can download and upload most applications (a HD resolution video can be transmitted with bandwidth of 3-7 Mbps);
- can support asymmetric download and upload, as we use connectivity to "consume" content more than we do to send content; and
- provides a low bandwidth "always-on connectivity" to support background data requirements for applications.

Indoor connectivity is the main service issue for mobile consumers

Consumers typically use fixed broadband and mobile broadband services for all their apps. Further, newer technologies such as instant messaging and streaming services are supplementing (and gradually substituting for) consumer usage of traditional services (Voice, SMS and live TV).

However, mobile users can experience performance issues and ComReg has commissioned surveys to assess the particular problems consumers face[3][4]. Most Irish consumers indicated satisfaction with their current mobile service. However, consumers most use their mobile devices in the home for voice and data[5] and **indoor connectivity was highlighted as a key**

[3] Mobile Consumer Experience Survey – ComReg Document 17/100a.
[4] Ireland Communicates Survey 2017 – Consumer – ComReg Document 18/23a.
[5] Mobile Consumer Experience Survey – ComReg Document 17/100a slide 42 and 45.

issue impacting mobile consumers[6]. Rural consumers also tend to have a higher propensity to experience service issues than those who live in urban or sub-urban areas. Consumers reported performance issues at other locations or when travelling, although at a lower rate.

Ireland faces challenges in providing connectivity

Summary of key points
Ireland is one of the most rural countries in the EU28.
76% of Ireland covered in farmland and forestry.
3% of the population of Ireland live in 28% of the geographic area.
Road density in Ireland is twice the EU average per road user.
Building materials act as a barrier to mobile signals limiting indoor connectivity quality.

Large parts of Ireland are rural

Providing connectivity in Ireland is very challenging. Population density is 69 persons per square km in Ireland compared to the European average of 117 persons per square km.[7] Of all EU Member States, Ireland also has the highest proportion of population that live in NUTS 3 areas[8] classified as Rural.

76% of Ireland covered in farmland and forestry

Farmland and forestry accounts for 76% of the total area of Ireland or around 5.2 million hectares.[9] The ratio between farmland and the total area of Ireland is the highest in the EU[10].

Ireland's population is not dispersed uniformly. The urban population accounts for 63% of the total but is located in just over 2% of the total area of Ireland.

6 Mobile Consumer Experience Survey – ComReg Document 17/100a slide 42 and 45.

7 Source: Eurostat

8 There are 8 NUTS 3 regions in Ireland. Each NUTS-3 region is classified as predominantly rural, intermediate or predominantly urban based on certain thresholds of population size and density. These thresholds are applied to combinations of grid cells of 1 km square to get a proportion of rural areas within a given NUTS-3 unit. Units where less than 20% of the population is urban are predominantly rural, those with 20%-50% rural populations are intermediate areas and the rest are predominantly urban.

9 Annual Review and Outlook for Agriculture, Food and the Marine 2016—2017

10 Source: "http://ec.europa.eu/eurostat/statistics-explained/index.php/Farm_structure_statistics

Conversely, 37% of the population is spread across 98% of the area, with **just 3% of the population located in 28% of the area of Ireland.**[11]

Ireland also has a high proportion of "one-off housing" in rural areas. One-off housing describes housing stock that is the result of developments of single dwellings, as opposed to planned developments of multiple dwellings. According to the 2016 census[12], 71.8% of the houses in rural areas are categorised as one-off houses[13].

This creates challenges in providing connectivity to sparsely populated areas due to the high fixed costs of network infrastructure over thinly distributed populations.

Ireland has one of the highest densities of roads per capita in Europe

Ireland's road network is extensive with 5,306 km of primary and secondary roads[14]. There is a further 91,000 km network of regional and local roads[15]. Ireland's extensive road network presents challenges to mobile operators.

100,000 km's of roads
Twice EU average/pop

The road density in Ireland, measured at 21 km per 1000 inhabitants, is twice the EU average. Outside of urban areas, mobile operators provide coverage in areas where their customers are located. Therefore, while they may build dedicated capacity to support connectivity on the most used roads, the sheer volume of roads (compared to users) in Ireland means that this is only economically viable on the busier and larger road networks[16].

Environmental standards & building materials affect connectivity experience

There are also challenges to connectivity from environmental standards that improve building insulation and efficiently keep cold out and heat in. This is because a consequence of meeting these important environmental goals is that it reduces connectivity indoors.

A recent report by ComReg[17] finds that the use of modern building materials, windows, block materials and roofing can have a significant detrimental effect on the propagation of radio waves into buildings constructed using these materials.

11 Source: Central Statistics Office, E2014: Population Density and Area Size.

12 Source: Central Statistics Office.

13 Source: http://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/Define.asp?Maintable=E1063&Planguage=0

14 Source: http://www.tii.ie/roads-tolling/our-road-network/

15 Source: http://www.dttas.ie/roads/english/regional-and-local-roads

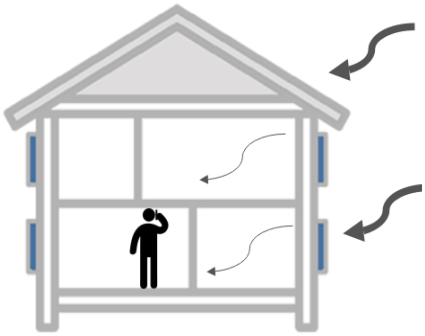
16 Providing mobile connectivity to serve transport routes requires masts to be erected in appropriate areas and or access provided to ducts where required. Such requirements can require development consent, planning permissions or roadworks licences and has often limited the extent to which roadside coverage can be provided.

17 The Effect of building material on indoor mobile performance – ComReg Document 18/17.

ComReg observed that this challenge seems likely to be further exacerbated as building and insulating materials used become even more energy efficient (e.g. important schemes such as the "Better Energy Homes".)[18] **The losses suffered by radio waves penetrating these materials is in the order of 20 to 60 dB** (which is sufficient to significantly reduce or even prevent connectivity in some cases)**.**

Signal strength is affected by other environmental factors (such as large objects in between devices and cell towers). Other factors such as the distance from the cell tower, or the handset can also affect the connectivity experience. Jointly the inter-play of these factors will affect users' experience which will, by definition, vary as mobile services are used at different locations, for different purposes.

Signal strength reductions of 100 to 1,000,000



Given these challenges it is inevitable that in some cases mobile networks may not provide indoor mobile connectivity without recourse to other solutions such as Native Wi-Fi or mobile repeaters.

Targeting high speed mobile connectivity on a population basis is commercially attractive

Summary of key points
➢ Targeting at least 90% on the population for 30 Mbps is likely to be commercially attractive. By contrast targeting 99.5% high speed mobile geographic coverage would cost almost €1.9 billion and therefore would not be a viable proposition for commercial operators.
➢ Extending mobile coverage to reach 90% population coverage for 30 Mbps will also importantly provide significant coverage improvements for motorways, primary roads and geography, and achieve above 99% population and 90% geography coverage for 3 Mbps.
➢ Consumers do not appear to have a high willingness to pay for additional connectivity improvements.
➢ Appropriate connectivity provision will require a balance of real world costs and consumer benefits.

[18] https://www.seai.ie/grants/home-grants/better-energy-homes/

The challenges of providing mobile connectivity in less densely populated areas mean that costs rise exponentially for each remaining percentage of geographic area covered, while the incremental benefits of providing coverage decline as fewer and fewer users benefit in iteratively less dense areas.

A recent study for ComReg[19] estimated that the costs of increasing mobile coverage of **30 Mbps to 99.5% of the country would cost €1,860m on a geographic coverage basis**[20] **and €511m on a population coverage basis**. These costs decrease substantially as the level of coverage reduces downwards from the 99.5% coverage level, thus indicating that providing coverage to last few percentile of the country is costly.

In considering the results of this study, it is important to note that, **the 30** Mbps service modelled is a mobile service and is not the same level of service outlined in the NBP service requirements which are notably higher.

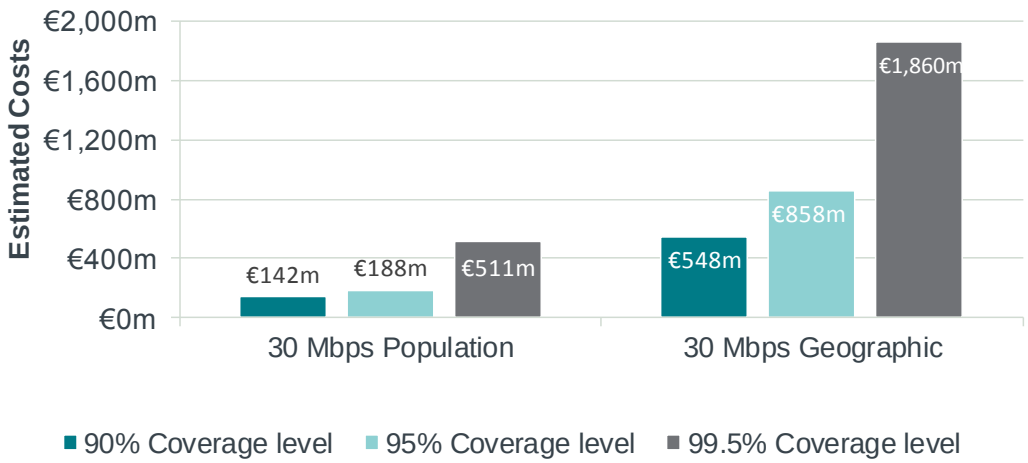
In particular, the NBP proposed a *minimum* level of service of 30 Mbps to premises and bidders were also requested to provide a **future proofed** network which responded to growing demand for bandwidth. This is to ensure that end users in the NBP Intervention area receive a reliable and consistent high speed broadband service indoors. The technical differences between a mobile and fixed network[21] inevitably mean that a 30 Mbps service on a mobile network is a *theoretical minimum achievable for outdoor coverage*. The actual experience could be lower and will depend on a range of issues such as the number of other users in the cell and factors that affect the quality of the mobile signal such as objects (such as buildings / walls) in between the user and the base station. Fixed networks are not affected by the same factors.

[19] ComReg Document 18/103c

[20] Note that this figure was provided in order to provide a sense of the monetary cost. However, this is based on a network roll-out CAGR of 19.96% (from mid-2020) which is unlikely to arise given the current rollout rate of 2.5%. Building the build the network at a rate of 2.5% would achieved full geographic coverage after 2070. Therefore, full geographic coverage is unlikely to arise due to both time and cost considerations. See Section 5.3.4 of FMC Report.

[21] As discussed in section 4.

Figure 1 Costs of roll out at different data speeds

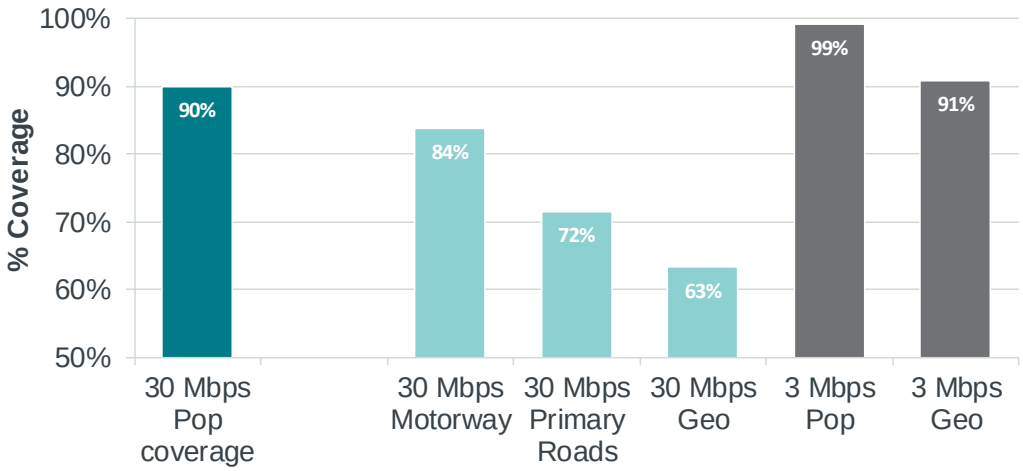


Source: FMC report.

This study also indicates that **targeting high levels of at least 90% of population coverage for 30 Mbps is likely to commercially attractive for the market** and that this will importantly lead to significant improvements in coverage for other coverage dimensions. As indicated below, if an MNO extends its network to achieve 90% population coverage of 30 Mbps, then it would (simply by virtue of where people live) incidentally achieve:

- above 80% motorway, 70% primary road and 60% geographic coverage for 30 Mbps; and
- above 99% population, and 90% geographic coverage for 3 Mbps.

Figure 2 Incidental coverage resulting from 30 Mbps population coverage



Source: FMC report

Some measures such as choice of handset, choice of network or the roll out of new spectrum bands (such as the 700 MHz band) will improve the connectivity experience even in the most rural areas. However, if network operators provided

full geographic coverage in the most rural areas, mobile infrastructure in those areas would remain under-utilised.

Based on past experience in the Irish market and for obvious economic reasons, mobile operators are less willing to roll out high speed connectivity in areas that would be significantly under-utilised. For example, currently, geographic coverage of high speed mobile connectivity (i.e. at least 30 Mbps) is estimated to stand at 18.3 per cent.[22]

Consumers' willingness to pay is not aligned with the cost of increasing coverage with just 12% willing to pay more for incremental geographic coverage. The average willingness to pay for incremental coverage was an extra €2.17 (7%) and €1.98 (6%) per month for additional voice and data coverage respectively. This is another factor likely to influence the commercial attractiveness of extending population coverage as opposed to targeting geographic coverage.

Furthermore, there is greater scope for variation in service quality in rural areas compared with urban areas. Where mobile users are further away from the site, or there are challenging topography features (e.g. geographic obstacles such as hills or trees) to overcome, the signal strength drop hampers the connectivity experience.

If public funds were used to fund incremental mobile coverage the Irish Government should have to balance the overall benefits against the costs, taking into account the extent to which alternative investments and initiatives to improve connectivity could achieve similar benefits.

NBP and network upgrades support connectivity

Summary of key points
➢ NBP has a central role in providing connectivity solutions for consumers who would not obtain high speed connectivity absent the intervention.
➢ Fixed broadband supports connectivity for fixed & mobile devices indoors.
➢ Native Wi-Fi functionality allows consumers to seamlessly make and receive voice calls on mobile devices indoors without use of external applications.

The availability of fixed and mobile networks in Ireland is relatively high against most European benchmarks. Ireland ranks relatively high in its connectivity (Ireland ranked 11 out of the EU 28) according to the European Union's Digital Economy and Society Index (DESI) 2018[23] and has slightly lower than average coverage of

[22] ComReg Document 18/103c

[23] Ireland ranked 11 out of 28 in the Digital Economy and Society Index (DESI) 2018, Connectivity Index. *"The connectivity dimension looks at both the demand and the supply side of fixed and mobile broadband. Under fixed broadband, it assesses the availability as well as the take-up of basic, fast (Next Generation Access – NGA providing at least 30 Mbps) and ultrafast (at least 100 Mbps) broadband and also considers the prices of retail offers. On mobile broadband, the availability of 4G and the take-up of mobile broadband are included. Digital Connectivity is considered as a social right in the EU."* The DESI is a composite index that summarised indicators on fixed and mobile connectivity, human capital, usage of internet services,

high speed (> 100 Mbps) fixed networks. However, availability of fast broadband will increase in the coming years as operators such as eir, Siro, and ENet are investing in the roll out of fixed FTTH networks; and the NBP envisages rolling out a fibre network to c. 540,000 premises, such that all remaining Irish households can receive high speed broadband with speeds of at least 30 Mbps.

THE NBP

In 2012 the Department of Communications, Energy and Natural Resources (now Department of Communications, Climate Action and Environment (DCCAE)) launched a National Broadband Plan (NBP), which would provide high speed broadband to Irish households. The plan aimed to achieve:

- 70 Mbps – 100 Mbps available to at least 50% of the population with a majority having access to 100Mbps;
- at least 40 Mbps, and in many cases much faster speeds, to at least a further 20% of the population and potentially as much as 35% around smaller towns and villages; and
- a minimum of 30 Mbps available to all.[24]

The NBP should also increase access to fibre backhaul in rural areas reducing the cost of providing mobile services. It will also support in building use of Wi-Fi on mobile devices (such as Native Wi-Fi voice calling). Furthermore, denser fibre networks in more rural areas could enable new forms of connectivity such as community Wi-Fi networks.

Fixed Broadband supports connectivity across multiple devices

Fixed broadband supports connectivity across multiple devices and services. This includes the data connections from laptop or desktop computers, IPTV, data on mobile devices (such as smartphones and tablets) and voice connections from "native Wi-Fi" (i.e. voice calls on a smartphone device / subscription routed through a fixed Wi-Fi connection). Thus consumers' connectivity is supplied by an overlapping set of networks which will vary during the day (i.e., according to whether the consumer is at home, work, travelling or elsewhere).

Although originally conceived as voice networks, mobile networks have adopted new standards, new technologies, and spectrum released by Governments to support data services. 99% of households

integration of digital technology in businesses and digitisation in public services. On the connectivity dimension, Ireland scores well with a particularly strong score in Mobile Broadband connectivity.

[24] https://www.dccae.gov.ie/documents/National%20Broadband%20Plan.pdf

have 3G coverage and 97% have access to 4G[25]. ComReg has supported connectivity by managing the release of spectrum to support a range of services providing connectivity to consumers.

Given that consumers' reported main use of their mobile handset is to make and receive calls within the home, **native Wi-Fi provides the opportunity for consumers to significantly increase their mobile voice experience indoors.** This represents an efficient way of providing high quality voice calls from a mobile handset. eir is the only Irish mobile network operator (MNO) to have rolled out native Wi-Fi calling on its network and is currently adding additional supported devices to extend the reach of the service. Vodafone plans to launch "VoWifi" (Voice over Wi-Fi) during 2018, which will provide a similar service for Vodafone customers.[26]

Stakeholders have a role in enabling connectivity

NBP is an important public intervention which will provide connectivity gains to end users, who would not have access to such connectivity absent the intervention. In addition to this ongoing public intervention, stakeholders (**Government, End users, ComReg and Industry**) can act in mutually supportive ways to improve consumers' connectivity experience.

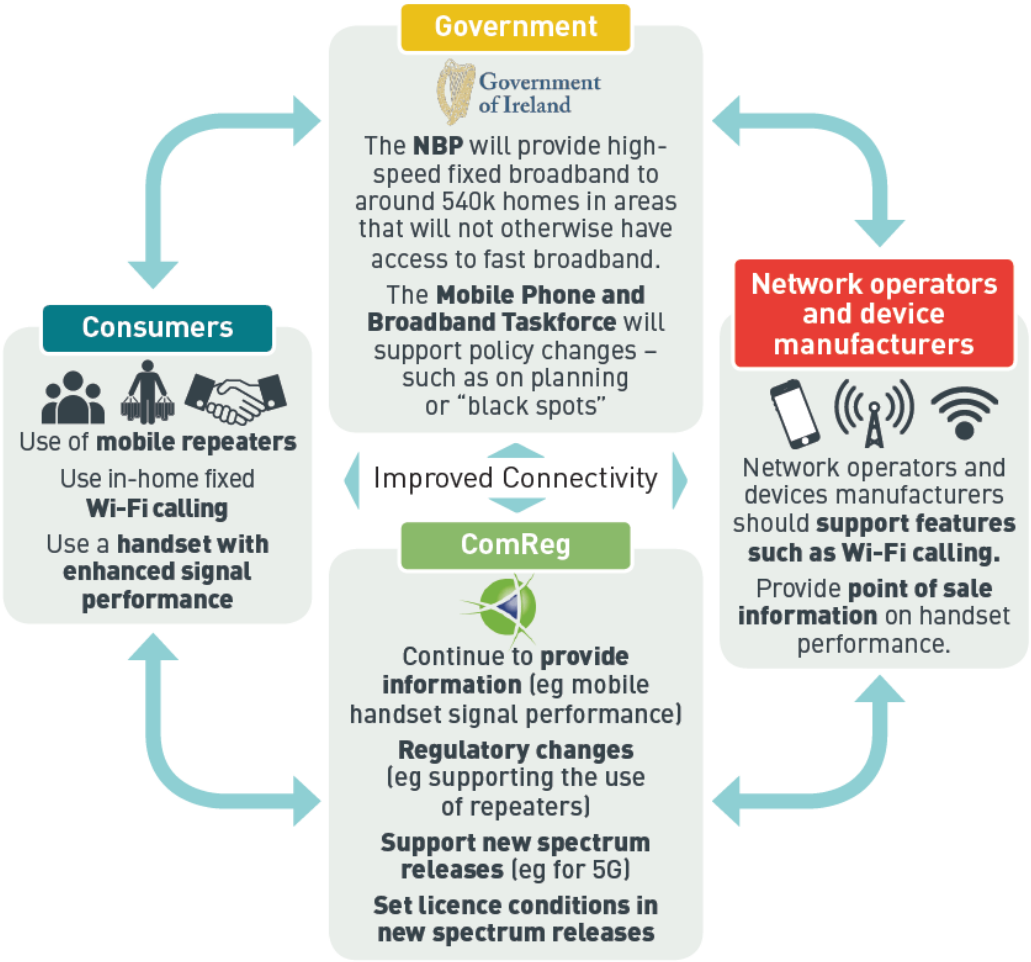
These complementary actions and strategies are already being adopted, and others which can be adopted in the future can enhance the connectivity experience in a targeted and proportionate approach. For example there are a range of measures which, in combination, could mitigate many existing connectivity issues (such as in-building connectivity in rural areas). However, providing full geographic coverage (to erect and maintain under-utilised cell sites), to all unpopulated areas is necessarily very costly, with limited associated benefits. Therefore, while there are a range of measures that will iteratively improve the connectivity experience in the most rural areas, it is likely that mobile connectivity experience in the most rural, unpopulated areas, will never be the same as in more densely populated areas.

The stakeholders and the key contributions to improving connectivity are outlined below.

[25] Digital Economy and Society Index Report.

[26] Kennedy, J. (2017), 'Vodafone to launch voice over 4G and Wi-Fi in Ireland in early 2018', 26 July, https://www.siliconrepublic.com/comms/vodafone-voice-lte-Wi-Fi

Figure 3 Stakeholder actions to improve connectivity



Source: Frontier

Government

Government departments and agencies are central to addressing bottlenecks and creating efficiencies in the delivery of services. It is also best placed to lead interventions in those areas where commercial operators are unlikely to provide services. In that regard, the Governments role includes the following.

- The **National Broadband Plan** is a key infrastructure project and its stated ambition, to deliver high speed broadband services to all businesses and households in Ireland, is key to the future provision of connectivity in rural Ireland. This project is expected to bring fibre-based connectivity to c.540,000 premises. It also underpins much of the connectivity improvements that can be taken by consumers individually and is, therefore, essential to providing an effective solution to indoor voice and data connectivity.
- The Government has instituted the **Mobile Broadband Taskforce** ('MBT') to provide identify constraints which can impede connectivity, recommend policy solutions and coordinate actions. The MBT's activities are therefore important in removing bottlenecks and improving efficiency. These include:

- Reducing the cost and streamlining planning processes for the deployment of telecommunications infrastructure (Actions 7 – 11 MBT).
- Installing ducting on new national primary/secondary roads (Action 6 MBT).
- Developing and publishing a policy for all local authorities around access to and use of state infrastructure (Action 18 MBT).

- The European Commission and European Investment Bank's **Connecting Europe Broadband Fund**[27] targets "black spots"[28] in less populated and rural areas, providing a source of finance where commercial operators don't provide connectivity.

End users

Many end users do not realise that there are many minor often low-cost actions which can improve their connectivity experience. These are often not taken because consumers are unaware that such measures are available to them. Examples include:

- The choice of **mobile handset** can significantly affect the connectivity experience.
  - Research conducted by ComReg on mobile handset performance[29] for voice suggests variation in performance of up to 14 dB between handsets, which means that some handsets have significantly poorer reception than others.
  - Native Wi-Fi calling is not available on all handsets and is typically available only on more recent phones. Consumers should consider Native Wi-Fi calling functionality as a key feature when deciding on a handset.
- The choice of **mobile operator** can significantly affect the connectivity experience.
  - Research conducted by ComReg[30] shows that nearly half of all consumers who switched mobile operator experienced improved mobile coverage.
  - Currently not all mobile operators offer native **Wi-Fi calling**. eir is the only mobile operator currently offering native Wi-Fi services. Consumers should consider Wi-Fi calling as important competitive differentiator when choosing a service provider.
- Consumers should also consider the use of **mobile phone repeaters** in areas where mobile voice connectivity is poor in and around a household and a reliable internet connection is not present. ComReg has put in place licence exemption arrangements for the general usage of these devices.[31]

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27 See: https://ec.europa.eu/commission/news/investment-plan-first-eu-fund-fully-dedicated-broadband-infrastructure-unlock-least-eu1-billion-over-5-years-2018-jun-27_en

28 Black spots are areas where users are unable to access connectivity.

29 See Mobile Handset Performance (Voice) ComReg Document 18/05.

30 See Mobile Consumer Experience Survey ComReg Document 17/100a.

31 See Mobile Phone Repeaters - Response to Consultation and Final Decision ComReg Document 18/58.

ComReg

ComReg continues to implement a number of measures aimed at improving the connectivity experience. For example, ComReg:

- Recently published a Technical Report (ComReg Document 18/05) into **mobile handset voice performance**. ComReg has published a further report[32] will provide results in relation to data[33] and updates will be provided at regular intervals.
- Recently published its report on 'The Effect of **Building Materials** on Indoor Mobile Performance'[34]. It will continue to examine the overall effect of building materials and will consider how to best establish the aggregate effect on signal propagation.
- Provides **information to consumers and industry** including price comparisons[35] and advice on mobile service issues[36];
- **Conducts research** on mobile phone user experiences and perceptions[37] and telecommunications generally in order to inform itself and other stakeholders of the issues faced by end-users.
- **Continues to consider the releases of additional spectrum** to support the increased demand for connectivity. ComReg's preliminary consultation for the upcoming multi band spectrum award includes 470 MHz of spectrum, with 350 MHz being additional spectrum that is currently not used for Wireless Broadband. This includes the proposed assignment of the 700 MHz band which is suitable for wide area coverage.[38]
- Intends to generate **a national coverage map** by the end of 2018 from comprehensive data, including data provided by operators and made this available on its consumer website.
- Intends to consider **coverage and rollout obligations** as part of the next multi-band spectrum award to provide for the efficient use of the radio spectrum and promote competition to the benefit of consumers. ComReg has commissioned a report[39] which has set the key considerations in designing a set of coverage obligations that result in socially optimum coverage levels.
- Continues its programme of Bi-Annual Drive Testing - Assessment of Mobile Network Operators' **Compliance with Licence Obligations** (Coverage).

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32 Expected to be published in October 2018.

33 Mobile Handset Performance – data ComReg Document 18/84.

34 See The Effect of Building Materials on Indoor Mobile Performance ComReg Document 18/73.

35 https://www.comreg.ie/compare/#/services

36 https://www.comreg.ie/consumer-information/mobile-phone/service-issues-2/

37 https://www.comreg.ie/comreg-publishes-results-irish-mobile-phone-user-experiences-perceptions-national-survey/

38 Proposed Multi Band Spectrum Award - Preliminary consultation on which spectrum bands to award ComReg Document 18/60

39 DotEcon ('DotEcon Report') 'Coverage obligations and Spectrum Awards' ComReg Document 18/103d,

Network operators and equipment manufacturers

There are a number of actions that can be taken by industry (network operators and equipment manufacturers) to improve connectivity and maximise the extent to which end users, in their own right, can support their connectivity experience, thereby improving the efficiency of how existing networks deliver the optimum experience.

- Network operators will continue to **upgrade networks** and build capacity in capacity constrained areas. The Future Mobile Connectivity ('FMC') Report[40] estimates that operators are currently providing 96.7% of the population[41] with 3 Mbps and voice services. Operators are likely to continue rolling out services commercially to serve large proportions of the population.
  - 85-90% population coverage (30 Mbps) up to 2024
  - 77-84% motorway (30 Mbps +Voice) and 95% national road (3 Mbps and Voice) coverage by 2024.
- Operators have adopted new networks for particular uses such as **Low Power Wide Area Networks** (LPWAN) specifically to support Narrowband IoT (NBIoT) devices[42]. Such technologies are also available in licence-exempt spectrum, meaning that end-users can deploy their own IoT network.
- Operators and handset manufacturers play a role in distributing to consumers **information on handsets** which offer Native Wi-Fi functionality or have superior signal performance.
- Other Mobile Operators could **prioritise the introduction of Native Wi-Fi** (Wi-Fi calling) which can mitigate indoor connectivity problems.
- Handset manufacturers and mobile handset retailers could **better inform customers** of the importance of handset signal performance and benefit of native Wi-Fi (for example providing point-of-sale advice).

40 ComReg Document 18/103c

41 Operators claim to have 97% population coverage but do not reference a minimum speed as part of this reference point. The modelled 96.7% refers to 3mbps at cell edge (i.e. 3Mbit/s represents a minimum mobile data rate)

42 See Vodafone for example. http://www.vodafone.com/business/news-and-insights/press-release/vodafone-is-first-to-announce-nb-iot-launch-markets

1 INTRODUCTION

ComReg commissioned Frontier to provide a report which illustrates and summarises the linkages between the activities of various stakeholders (government, regulators, operators, consumers, equipment manufacturers etc.) which have the potential to meet and improve the connectivity experience in Ireland and thereby support the productive capacity of the Irish economy. This report provides an overview of connectivity in Ireland, the challenges involved in improving connectivity and the actions that stakeholders can take to optimise levels of connectivity on different networks across Ireland.

“Connectivity” describes the ability of end users to connect and communicate with other end users and devices. It is now an essential element in modern economies.

Widespread and deep social and economic changes have been enabled by investments in telecommunications networks, devices and new software and other services. The adoption of data connectivity across consumer devices and business processes has fundamentally changed how we consume, purchase and communicate. It has transformed production and supply processes making economies more efficient.

“Connectivity” is partly related to the availability and capabilities of telecommunications networks. However, it also relates to the devices and handsets which use the networks; and the communication standards (whether 4G, Bluetooth or NFC standards) which enable different devices to connect to each other. Collectively these factors contribute to users’ experiences of connectivity.

Therefore, this report describes consumers’ current connectivity experience and the state of various networks in Ireland. It summarises the various on-going actions that are being taken by stakeholders to support connectivity. Finally, it identifies actions that all stakeholders can take to further improve the connectivity experience.

Some interventions, such as provision of mobile capacity in sparsely populated areas, are costly. In contrast, other interventions, such as use of repeaters where indoor signal is poor, use of Native Wi-Fi, or handset changes could achieve significant improvements in users’ connectivity experience in a more targeted and proportionate way.

The remainder of this report is set out as follows.

- Section 2 describes some of the trends and changes in the Irish market which are driving changes in connectivity.
- Section 3 summarises consumer needs for connectivity in Ireland and quality of service issues.
- Section 4 describes the challenges in providing mobile connectivity in Ireland.
- Section 5 explains that costs of providing connectivity in very rural areas are high.
- Section 6 summarises the state of networks in Ireland which collectively meet demand for connectivity.

- Section 7 sets out some of the actions that all stakeholders, whether end-users, government, ComReg, network operators and device manufacturers, can take to optimise levels of connectivity across different networks across Ireland.
- Section 8 concludes.

2 DEMAND FOR CONNECTIVITY

The key development in the use of networks in the last twenty years has been the rapid growth in demand for data connectivity. As a result of this growth in demand, networks which were originally designed for voice or TV have been adapted to support the transmission of data.

Connectivity is not of value in and of itself. Rather, it is an input into products, services and production processes. In this sense, the increasing demand for connectivity reflects changes in the use of devices, and the development of new applications.

We describe in this section how the growing sophistication of devices which are used with fixed and mobile networks and which offer ever greater processing power, for evermore complex applications, in turn require more data connectivity to support the applications. Similarly, we explain how the increasingly diverse applications and services that are available over mobile devices mean we require connectivity for services that did not previously exist.

Other trends are also driving demand for connectivity: our devices are now to some extent network agnostic and are typically designed to connect to any network (fixed and mobile) so we can use them anywhere, at any time. Furthermore, trends on content consumption mean there is a slow and gradual, but clearly identifiable trend to consuming content “on demand” rather than using the “traditional” terrestrial or satellite transmission networks. Finally, innovations in business use can drive demand for connectivity.

In the rest of this section:

- Section 2.1 summarises trends in growing demand for data connectivity in Ireland.
- Section 2.2 identifies some of the developments in applications and devices that we use which are driving our demand for data.
- Section 2.3 explains that devices are increasingly network agnostic, we expect to use all our applications on all our devices, any time wherever we are: whether at home, at work, when travelling or at leisure.

2.1 Demand for connectivity is growing

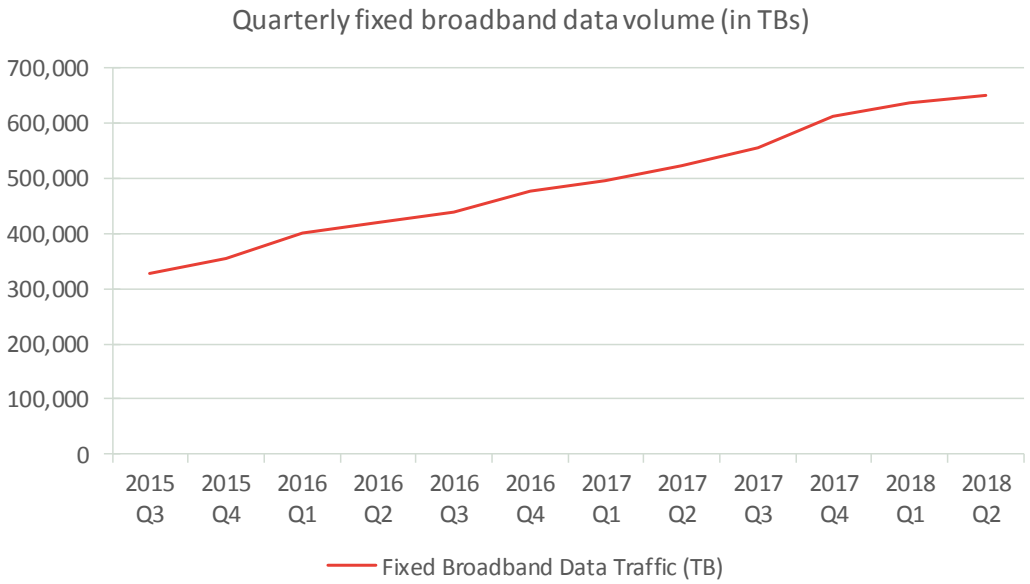
Demand for data connectivity has grown strongly across both fixed and mobile networks.

Fixed networks

The demand for connectivity in Ireland has increased considerably in recent years. For example, the total data carried on fixed networks has increased from 328,600 TB[43] per quarter in 2015 Q4 to 652,437 TB per quarter by Q2 2018 (an annual increase of 28%).

[43] 1 Terabyte (TB) = 1000 Gigabytes (GB), 1 GB = 1000 Megabytes (MB)

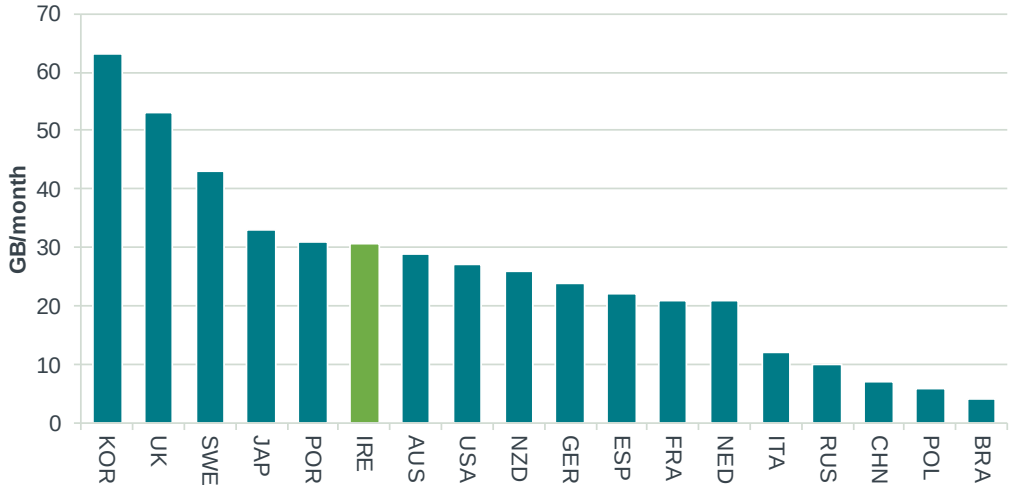
Figure 4 Quarterly fixed broadband data volume in Ireland (in TBs)



Source: Quarterly Key Data Reports ComReg

Data usage in Ireland is above other comparator countries, with per capita use higher, for example, than in Germany, Spain, France and Italy, although still below that in some of the countries considered to have the most advanced digital infrastructures, such as Japan and South Korea.

Figure 5 Per-capita monthly fixed data volumes (GB/month) (2016)



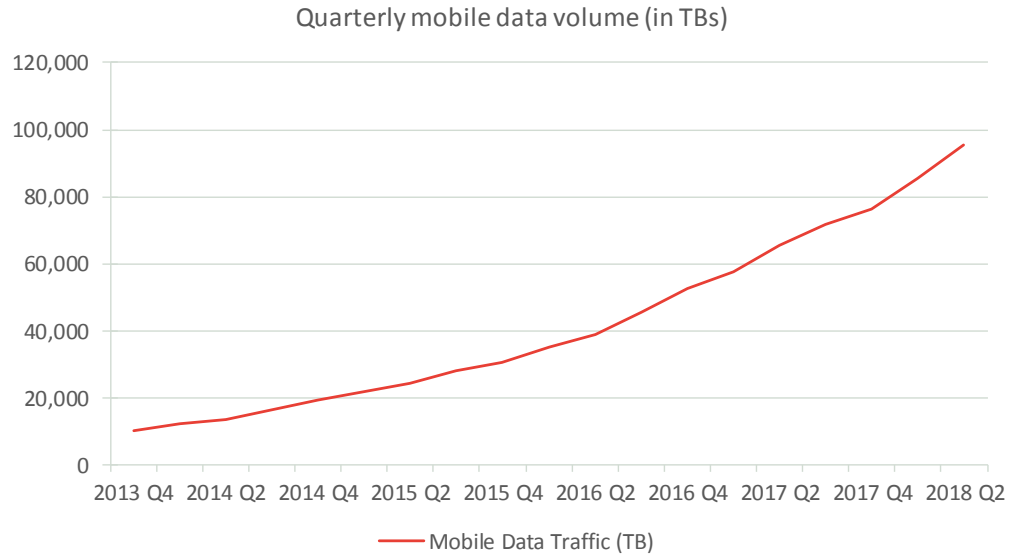
Source: Ofcom International Communications Market Report 2017, ComReg Doc 17/108 (Quarterly key data), CSO

Mobile networks

Total demand for data on mobile networks is much lower than on fixed networks, but has grown much more quickly in recent years, at a rate of 64% per annum. The

total data carried on mobile networks has increased from 10,401 TB[44] per quarter in 2013 to 95,464 TB per quarter by Q2 2018.

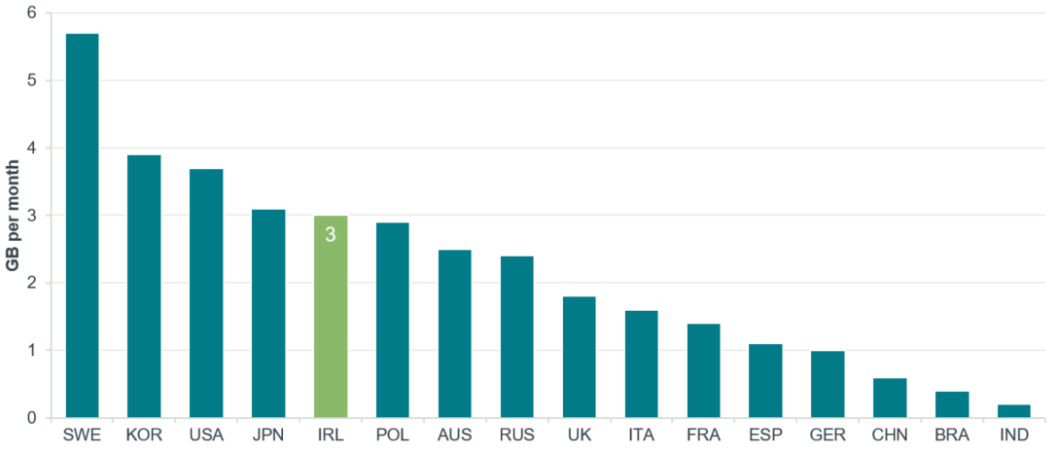
Figure 6 Total mobile data traffic (TB/quarter)



Source: Quarterly Key Data Reports ComReg

Again, mobile data usage in Ireland is above that (on a per capita basis) in a number of benchmark European countries, though behind global leaders such as Korea or Japan.

Figure 7 Mobile data use per capita (GB/month) (2016)



Source: Source: Ofcom International Communications Market Report 2017, ComReg Doc 17/108 (Quarterly key data), CSO

Mobile data forecast to increase

Mobile data usage will increase further. A recent publication by Frontier, commissioned by ComReg[45] noted that, mobile data demand is likely to increase by four times over the next five years from 268 million GB/year in 2017 to 1,059

[44] 1 Terabyte (TB) = 1000 Gigabytes (GB), 1 GB = 1000 Megabytes (MB).

[45] See Mobile Data Traffic Forecast in Ireland ComReg Document 18/35.

million GB/year in 2022. Despite limited expected increase in penetration of devices (since penetration is already very high) growth in demand for mobile data is likely to be driven by higher mobile data per device. This is driven by a number of trends. Consumers use mobile devices more, and for an increasingly wide range of uses. The services and applications that use mobile data are becoming more sophisticated and require higher bandwidth capability (for example to download or upload high definition video, or to simultaneously communicate with many other users). Supply side factors also are likely to influence mobile data demand. The roll out of faster, more advanced, mobile networks will unlock demand. Furthermore mobile operators will offer mobile packages which include "all you can eat" data plans, or other large data bundles which will influence consumer behaviour.

2.2 Changing devices, and uses of connectivity will drive demand for data

There are many factors that are, in combination likely to further increase demand for data which include the following:

- Devices are becoming increasingly sophisticated.
- Consumers are using more heterogeneous and sophisticated software and applications on our devices.
- Broadband networks are increasingly used by consumers to watch content that would be transmitted over terrestrial TV networks.
- Business applications continue to drive demand.

These drivers are all described in more detail below.

2.2.1 Devices are increasingly sophisticated

As we use ever more sophisticated devices which offer more advanced features and processing power, so demand for data connectivity using these features increases.

For example, this is seen in the trend of increasing screen size, screen resolution, processing power and camera resolution in mobile handsets, as mobile phones have developed from voice communication tools to a converged multimedia device capable of communicating in different ways (i.e. voice, text, and data). Figure 8 shows how all of these specifications have improved since 2007. The increased screen size and pixel density mean that smartphones load webpages or stream videos at a higher resolution, both of which require more data to be transmitted to the handset.

Figure 8 Evolution of smartphone specifications

	iPhone	iPhone 4	iPhone 6	iPhone 7 Plus	iPhone X
Year of release	2007	2010	2013	2015	2017
Display	3.5"	3.5"	4.7”	5.5”	5.8”
Pixel density	163 ppi	326 ppi	326 ppi	401 ppi	458 ppi
CPU	Single core 412 MHz	1.0 GHz Cortex-A8	Apple A8 (1.4 GHz)	Apple A10 Fusion (2.34 GHz)	Apple A11 Bionic (2.39 GHz)
Camera Resolution	2 megapixels	5 megapixels	8 megapixels	12 megapixels	12 megapixels Dual

Source: *http://socialcompare.com/en/comparison/apple-iphone-product-line-comparison*

Notes: ppi relates to pixels per square inch

The increasing processing power of devices coupled with developments in battery technology also means that software providers can provide more sophisticated applications and services that run on these devices. These can include video editing applications, 3D video, or high-end gaming. Applications are also expanding their functionality which increases demand for data. For example, Instagram previously limited videos to one minute, however since June 2018 the latest version has allowed videos of up to an hour in length.[46]

[46] https://instagram-press.com/blog/2018/07/27/the-best-of-igtv-this-month/

FEATURES OF SMART PHONES BOOSTED DEMAND FOR DATA

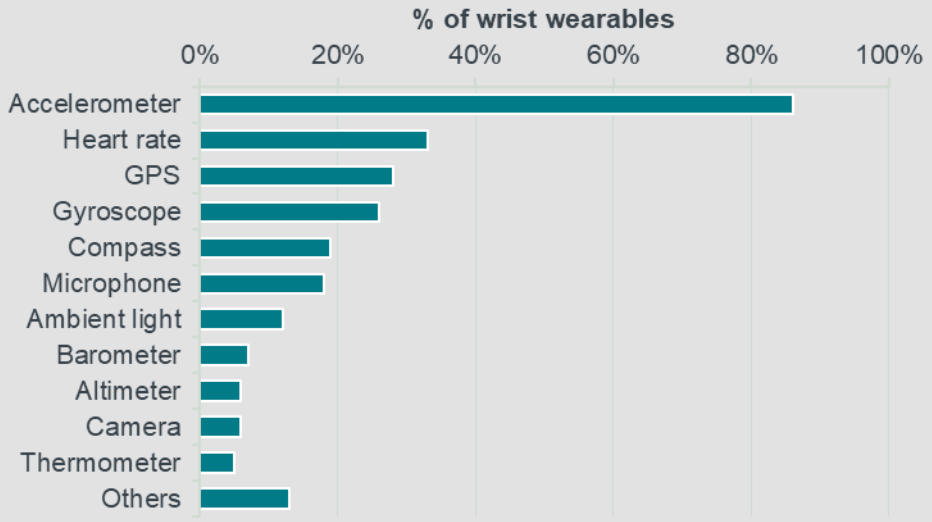
The advent of smartphones significantly spurred demand for mobile data. Smartphones are defined as mobile handsets that can be customised by users by downloading apps and content directly onto the handset. Smartphones had been on the market since the early 2000s (for example from manufacturers such as Blackberry and Nokia). However, it was in 2007 with the launch of the iPhone, and the following year with the launch of Google's Android mobile operating system, that demand for data took off.

Arguably it was certain features of the iPhone and similar Android devices which boosted demand. These handsets offered large screens for consuming audio visual content and their user interfaces were designed around user-friendly touch screens. These features, alongside "open" application stores selling apps from developers, changed our demand for data connectivity.

NEW DEVICES SUCH AS SMARTWATCHES CONTINUE TO DRIVE DEMAND

Manufacturers are also developing other new products. For example, technology embedded in "Smartwatches" or fitness bands (owned by 5% and 8% of Irish adults[47] respectively) are gaining popularity. Smartwatches and fitness bands combine several different sensors which in turn can drive demand for new products and services (whether fitness applications or activity tracking applications). For example, **Figure 9** illustrates the types of sensors that are found on smartwatches and fitness bands. These can be used to support a wide variety of different services or applications. More generally, wearables devices are forecast to have a tangible impact on mobile traffic, because even without embedded mobile connectivity, wearables can connect to mobile networks through smartphones. As high bandwidth applications such as virtual reality gain popularity the demand for data might increase faster than currently foreseen.[48]

Figure 9: Sensors in wrist wearables (September 2018)



Source: Mary Meeker Internet Trends 2017; Note: Relates to November 2016

2.2.2 The applications that we use are increasingly diverse

The increasing processing power, features and hardware incorporated into devices mean that the applications that we use are increasingly diverse: consumer demand for connectivity is derived from the wide range of apps and services that rely on data. For example, the evolution of device and software technology has meant that there are a plethora of new uses of technology whether satellite navigation, traffic monitoring, health monitoring, shopping, finance and digital assistants.

As mobile handsets have become multi-function devices they are now used to deliver a wide variety of services. Not only do consumers use mobile broadband to

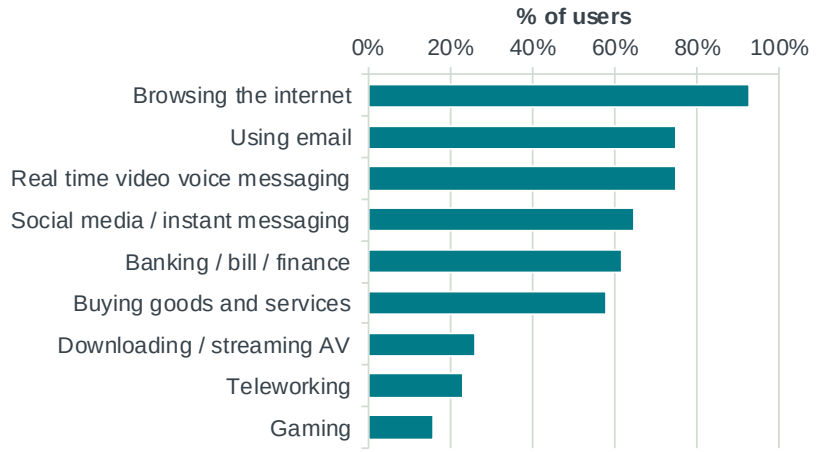
[47] Source : https://www2.deloitte.com/content/dam/Deloitte/ie/Documents/TechnologyMediaCommunications/Global_Mobile_Consumer_Survey2016.pdf

[48] The Cisco® Visual Networking Index (VNI) 2017.

browse the internet (93%) and send and receive emails (75%), but 75% of consumers use broadband for real time video and/or voice messaging, 62% of consumers reported using their mobile broadband services to manage their finances and/or pay bills; and 58% use it to buy products or services online. 42% had reported making a video call in the previous six months[49]. Further, the connectivity required for different uses varies substantially and more recent applications tend to be data heavy. For example:

- One hour of browsing through social media can use up 90 MB (megabytes).[50]
- A Standard Definition (SD) Netflix stream uses 0.7 GB per hour, High Definition (HD) up to 3 GB per hour and Ultra HD up to 7 GB per hour [51]; and
- A typical hour of live TV streaming will consume around 540MB of data for SD and 1.8GB for HD content[52]

Figure 10 Services accessed via mobile broadband



Source: Ireland Communicates Survey 2017 ComReg Document 18/23a

All these activities are supported by standard data connections. However, in addition to these mass market applications, there are a number of more niche applications aimed at distinct customer groups that might have more specific connectivity requirements (Figure 11).

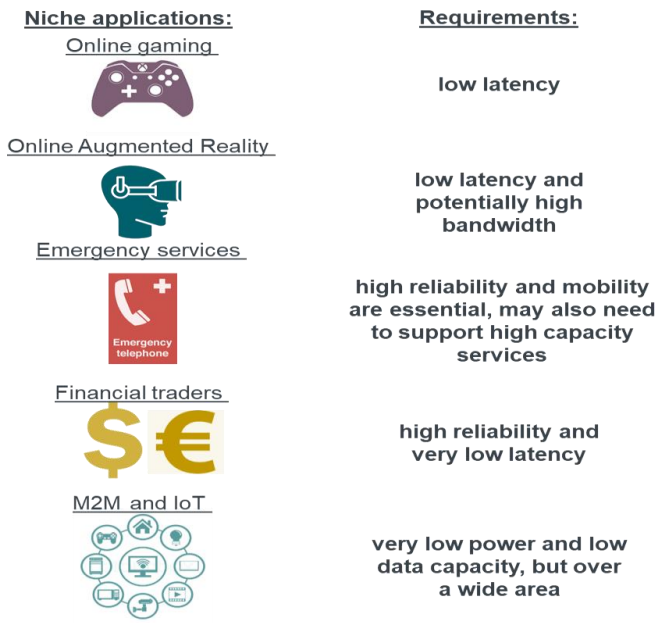
[49] See: Ireland Communicates Survey 2017 ComReg Document 18/23a

[50] Source: Cisco's VNI Services Gauge Tool http://www.cisco.com/c/en/us/solutions/service-provider/vni-service-adoption-forecast/vnisa_services_gauge.html

[51] https://help.netflix.com/en/node/87

[52] https://n.vodafone.ie/support/tv-hub/tv/vodafone-tv-anywhere.html

Figure 11 Connectivity requirements for niche applications



Source: Frontier

2.2.3 IP transmission is replacing traditional broadcast transmission

Increasingly, fixed networks at home are used to provide access to TV and radio content that would in the past have been provided via terrestrial TV transmission networks. Many households have either integrated connectivity in their TV or set top box, or alternatively may have a dedicated streaming dongle to enable viewing on a TV set. Indeed, according to Television Audience Measurement Ireland (TAM) there are around 30,000 homes in Ireland that use only their internet connection to access TV services.

26% decline in viewing of live TV by younger viewers

15-24 year olds in Ireland between 2012 and 2016

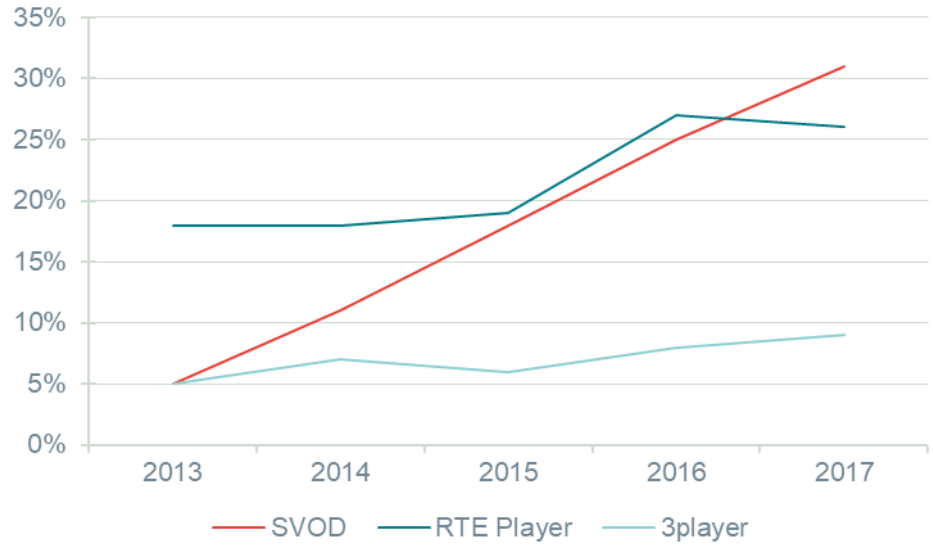
This provides access to on demand content, whether via subscription services or free services. According to a recent report for the Broadcasting Authority of Ireland (BAI), Netflix was available in a third of Irish households[53]. In addition, free services such as RTÉ Player from RTÉ and 3Player from TV3 (TV3 has recently been rebranded to Virgin Media Television)[54] are increasingly used by consumers. According to the 2017 Ireland Communicates survey, 30% of Irish households use catch-up players.

[53] Broadcasting Authority of Ireland, A report on market structure, dynamics and developments in Irish media, December 2017.

[54] https://www.virginmedia.ie/about-us/press/2018/tv3-group-to-rebrand-as-virgin-media-television/

Figure 12 shows the penetration of subscription Video on Demand (VoD) services as well as RTÉ Player and 3Player.

Figure 12 Use of VoD in Ireland



Source: Broadcasting Authority of Ireland, A report on market structure, dynamics and developments in Irish media, December 2017

Not all the consumption of VoD services will displace viewing of live TV transmission services. 95% of those with subscriptions to streaming services reported that they continued to watch broadcast/scheduled TV but 51% admitted that they now spent less time on it.[55]

It is noteworthy that the total average viewing of live TV has declined from 185 minutes per day in 2012 to 166 minutes per day in 2016 (a 10% decline). The decline in viewing of live TV is even more marked for younger viewers whose volume of live viewing has declined by 26% in the same period.[56]

We would expect that as fast fixed broadband connections become ubiquitous that the broadband networks will increasingly supplant one-to-many terrestrial transmission services (though it is likely that a significant number of users may continue to rely on terrestrial networks in the near medium term). Indeed in 2018 Sky, the UK and Ireland satellite broadcaster, has announced that it will offer a full TV service delivered via broadband-only to complement its satellite service by the end of 2018[57].

2.2.4 Business applications driving demand for connectivity

In addition to consumer applications, business applications drive demand for connectivity. Such applications are important not just because they drive demand for connectivity. In addition services which are initially used in a business context

[55] See Ireland Communicates Survey 2017 (Consumer Survey), ComReg Document 18/23a.

[56] Broadcasting Authority of Ireland, A report on market structure, dynamics and developments in Irish media, December 2017.

[57] See: https://www.bbc.com/news/technology-38756577

can quickly become commonplace features in consumer products (push email is one example)[58].

Business uses of connectivity can include:

- **Online presence / website.** Businesses nearly all have an online presence which they use to attract customers and provide information. 95% of SMEs in Ireland reported having an online presence and 43% of SMEs noted that they use an online service to directly trade with customers[59].
- **Communications services.** Advanced communications such as video calling, multiparty video-calling and desktop sharing. 15% of SMEs reported using VoIP at least several times a month; 26% reported making a video call in the previous six months.
- **Teleworking and remote access**. Increasingly, workers need access to cloud based networks, including the ability to upload / download large files. 16% of Irish telecoms customers reported using their broadband connection to support teleworking (rising to 21% of users in rural areas).[60]
- **Machine to Machine communications.** Businesses are increasingly relying on Machine to Machine (M2M) communications. M2M connectivity is used in a variety of industries such as logistics, energy, industry and agriculture. M2M subscriptions now make up 14% of all mobile subscriptions. While the data demand for each M2M device is small, the numbers of M2M connected devices is expected to exceed 1.7 million by 2025 in Ireland.[61]

2.3 Devices have gone from being network specific to "network agnostic"

One important feature that affects demand for connectivity is that over time, devices have moved from being network specific to "network agnostic". That is, two decades ago, devices were specific to each type of network. Fixed networks used telephones for voice services or modems for dialup narrowband data services for home PCs. Cable networks offered cable TV set-top boxes to supply TV services, and mobile networks supported mobile phones which supported voice and text services, or pager services.

Now devices are designed to be "network-agnostic", meaning they are not designed for specific networks, but rather used on a range of different networks. For the majority of uses, consumers do not choose whether to access content on a fixed network *or* mobile network. Rather, instead, we use all the networks that our devices can connect to, depending the specific context.

This is driven by a number of factors.

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[58] Push email instant messaging is an example of an innovation which was initially aimed at business markets via mobile handsets such as Blackberry, but which were features which were incorporated into mass market devices.

[59] ComReg Ireland Communicates Survey 2017 SME Survey ComReg Document 18/23b.

[60] ComReg: Market Analysis Research Consumer Survey ComReg Document 16/96a.

[61] ComReg Draft Electronic Communications Services Strategy Statement: 2017 – 2019 ComReg Document 16/115, figure 2.

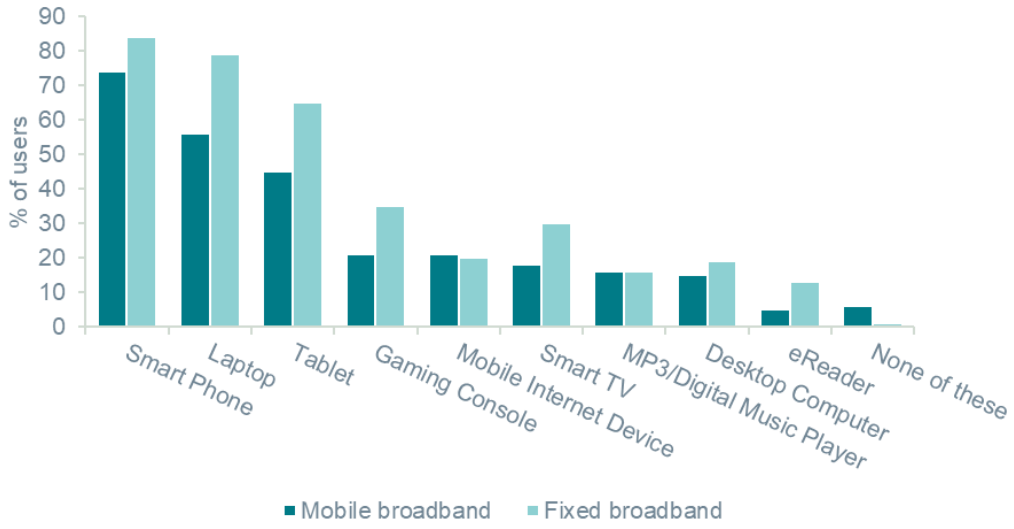
2.3.1 Device technology has developed to offer mobility

Devices are expected to be used at home and work, and across mobile and fixed networks. As such, devices can seamlessly roam across networks. For example, smartphones, tablets and laptops all connect in multiple ways to different networks[62]. In addition, improvements in battery, storage and processing power technology means that ever more sophisticated devices can be smaller and more user-friendly form factors (see section 2.2.1). Furthermore, each new device will have in-built antenna for mobile networks, Wi-Fi, Bluetooth and potentially others such as Near Field Communication (NFC).

Therefore rise in demand for connectivity partly stems from the larger array of devices that are being connected to mobile broadband services; 74% of consumers connect their smartphone and 56% connect their laptops to their mobile broadband service, whilst further devices which are frequently connected include tablets (45%), games consoles (21%), and smart TVs (18%)[63].

For example, according to a recent survey smartphones are equally likely to be connected to fixed as mobile networks. Whilst there are some differences in the propensity to connect devices to fixed and mobile networks, it is striking that all devices are used to some degree on both fixed and mobile networks.[64]

Figure 13 Use of Wi-Fi and mobile networks for different services



Source: Ireland Communications Survey 2017, ComReg 18/23a

Furthermore, devices can also directly connect and communicate with other standalone devices using a variety of standards to support connectivity. For example, laptops can tether to mobile connections, or devices can communicate using Bluetooth technology; while home equipment communicates with home PCs

[62] It is only a minority of devices which are inherently not portable and only used in the home that will tend to be designed to be used for fixed services (Smart TVs, set top boxes and gaming consoles).

[63] ComReg Ireland Communicates Survey 2017 SME Survey ComReg Document 18/23b.

[64] Devices such as laptops, tablets, Smart TVs, gaming consoles and, desktop PCs, are more likely to be connected to a fixed network than a mobile network.

using wireless routers. By connecting these devices individuals can create their own personal networks.

This means that consumers now expect to be able to access services on *all* their devices, whether at home, leisure or travelling. The devices we use are technology agnostic and are designed to roam between networks.

2.3.2 Data is stored on the cloud and accessed on any device

The "cloud"[65] is increasingly where we store data, software or applications. Two decades ago, software and content was stored on physical discs for specific devices. Now we access content directly from the cloud, rather than storing on our devices or physical storage.

Our content is held in archives in the cloud. Films or TV content is streamed direct from broadcasters or OTT services. Indeed video sharing OTT platforms such as YouTube offer a range of video content which is accessed at any time. Music is streamed from services such as Spotify, Apple Music, or Amazon Music. Devices now automatically upload photos to the cloud. Our emails, and social media is accessed direct from the cloud. Documents and projects are saved on the cloud to enable multiple users to collaboratively work together.

2.3.3 Fixed networks have evolved to support forms of mobility.

Fixed networks have evolved to support forms of mobility. All devices tend to use wireless connectivity to connect to a fixed network. This means that our mobile devices can be used around the home, work or other Wi-Fi locations such as Wi-Fi Hot Spots. Indeed at many public locations (cafes, shops, etc) the availability of Wi-Fi hotspots are seen as a "hygiene factor" not a point of competitive differentiation. The ability to roam onto a public fixed Wi-Fi network is seen as an essential service which customers expect.

[65] Cloud computing means storing and accessing data and programs over the Internet instead of your computer's hard drive.

3 CONSUMER NEEDS AND QUALITY OF SERVICE ISSUES

3.1 What are the important features of connectivity?

While data driven applications continuously evolve in new and unexpected ways, ultimately demand for connectivity to support most mass market applications is relatively predictable over time. Specifically, mass market users in Ireland require connectivity that:

- can support voice calls;
- offers bandwidth that supports consumer data applications (for example a HD resolution video can be transmitted with bandwidth of 3-7Mbps);
- can support asymmetric download and upload, as consumers use connectivity to "consume" content more than to send content;
- provides a low bandwidth "always-on connectivity" to support background data requirements for applications; and
- is available where consumers live, work, travel and spend leisure time (including in tourist areas).

Support for voice as well as data services

Fixed and mobile networks which were originally conceived and designed as voice networks now support voice, messaging and data. In practice, voice services are gradually substituting from traditional voice based technologies (such as the "Public Switched Telephone Network (PSTN) also known as the Plain Old Telephone System (POTS)) to "IP" networks. However, voice remains an important service on telecoms networks: there were four billion voice minutes[66] in Q1 2018 (total minutes had declined by 4% since Q1 2016).

4bn voice minutes per year

Made on fixed and mobile networks.

Bandwidth

It is likely that a 3 Mbps connectivity service is sufficient for basic connectivity[67]. For Higher Definition resolution a single user's demand is likely to be at most 7 Mbps currently. Even a "4K Ultra HD" video stream would only require around 25 Mbps for most programming (though potentially higher for sports content). Over time as demand for applications increases so will demand for connectivity. However, at most times, for most people, reasonably low bandwidth is sufficient, although in combination, a household with high demand might require multiple HD video streams at peak time. Fixed connections are typically per household,

[66] 3.2 billion mobile voice minutes and 0.8 billion fixed voice minutes.

[67] See footnote 44 and Annex 2 of ComReg Document 18/103c.

supporting multiple users, while mobile connections typically relate to individual users. Therefore, a household typically has a greater bandwidth requirement than an individual mobile user. [68]

Asymmetric demand

By far the biggest draw on data networks is video. For example, users reported viewing 10 minutes of video on their smartphone per day on average. This is likely to represent a significant proportion of the total data consumed during the day (i.e. around 1.25 GB per month)[69]. This places a significantly greater demand on downlink connectivity than uplink connectivity.

However, the increasing propensity to create and share content will increase the degree to which we upload content as well. This may reduce download upload asymmetry to a degree.

For example a recent study[70] found that;

- 21% of smartphone users in Ireland uploaded or shared photos using social networks or instant messengers;
- 12% of smartphone users in Ireland uploaded photos to a cloud based storage; and
- 16% of users in Ireland uploaded video.

In light of this asymmetric demand, developers have been improving the functionality of apps that consume large amounts of mobile data, which offers users the potential to improve their connectivity experience. For example, more and more apps offer preloading (or caching): letting the user download content on Wi-Fi and view it at any later time. Spotify, Netflix and Amazon Prime, for example, allow users to download playlists and programming to a user's device. Similarly, YouTube preloads subscriptions and videos on a Watch Later list. These improvements encourage consumers to interact with the increased functionality provided by applications.

Always on connectivity for background demand

Users require connectivity to support "background data" for their applications. "Background" data refers to automatic cloud synchronisation for certain applications even when they are not directly being used. These background data activities (i.e. those not specifically initiated by a user) are designed to support messaging, location based services, social networks and so on. Background data means that an app is using data even though the user is not actively using the application.

However, recent developer upgrades are increasingly allowing devices to effectively control background data usage on Wi-Fi only. For example, previous functionality on the iPhone OS (up as far as iPhone OS 10) only allowed for

[68] 75% of all private households contain more than one person. 50% consist of 3 persons or more and 30% consist of 4 persons or more. Census 2016, Households and Families.

[69] An hour long video uses approximately 250 MB – Cisco Services Gauge Tool.

[70] Global Mobile Consumer Survey Ireland 2016 Deloitte.

background data requirements to be switched on or off. However, the iPhone iOS 11 (released in September 2017), now allows the end user to decide to allow the feature only when they are on Wi-Fi or when on both mobile and Wi-Fi.

Connectivity where we live, work, travel and spend leisure time

Our changing use and attitude to connectivity means that we now wish to use all our devices, and applications wherever we happen to be. We require connectivity where we live, work, travel and spend leisure time. However, peak demands will differ across these areas and between mobile and fixed networks.

- At residential locations, peak demand is likely to be in the evening. For example Three noted to ComReg that there was a "*repetitive daily pattern*" of traffic on its network. In a typical working day "*the traffic volume grows steadily from about 16:00 and peaks between 18:00 and midnight with the busy hour occurring between 22:00 and 23:00*."[71] Consumers use their phone for voice and data most inside the home as opposed to other locations. For example:
  - nearly 70% use their mobile phone for voice or text in the house every day, falling to 60% in more rural areas[72].
  - 74% (45% every day) use their mobile phone for data usage at some point inside the home, rising to 82% (48% every day) for more rural areas.[73]
- At city centre locations where people work, peak demand might coincide with lunch times or the 5 o' clock rush from the office or place of work.
- At travel termini (train or bus stations) peak demand might coincide with commute travel times. On roads, peak demand might coincide with rush hour, or alternatively during a traffic event which holds up traffic.
- We also require connectivity in areas that attract high levels of tourism.

3.2 Some mobile users experience performance issues

The results of the Mobile Consumer Survey shows that while most Irish consumers indicated satisfaction with their current mobile service, some mobile users reported experiencing performance issues. Consumers can experience connectivity issues regardless of their location, but those issues occur more frequently at indoor locations and in more rural parts of the country. Rural consumers have a higher propensity to experience services issues than those who live in urban or sub-urban areas. Consumers also reported performance issues at other locations or when travelling, although at a lower rate. Consumers typically report a deterioration in

[71] Submissions to ComReg Document 15/140 ComReg Document 16/19. The day chosen is Friday 22nd January, which is a normal working day.

[72] Mobile Consumer Experience Survey ComReg Document 17/100a – Slide 43.

[73] Mobile Consumer Experience Survey ComReg Document 17/100a – Slide 46.

the quality of reception during a call, the inability to make calls and calls being unable to connect.

Mobile networks are designed to provide connectivity while moving and cannot reliably provide indoor connectivity given the variability in building materials that keep heat in and mobile signals out. This is particularly relevant given that inside the home is the most common location for consumers to use their mobile phone for voice and data[74]**.** Signal strength is also affected by other environmental factors (such as whether or not there is a direct line of sight between devices and cell towers), while other factors, such as the distance from the cell tower (see section 4.1), or the handset (see section 7.1.1) can affect the connectivity experience. Jointly the inter-play of these factors will affect users' experience which will, by definition, vary as mobile services are used at different locations, for different purposes.

In contrast, it is likely users' experience of fixed connectivity is more stable: at a given location and in most cases, the available capacity on the service can be predicted with reasonable degree of accuracy[75].

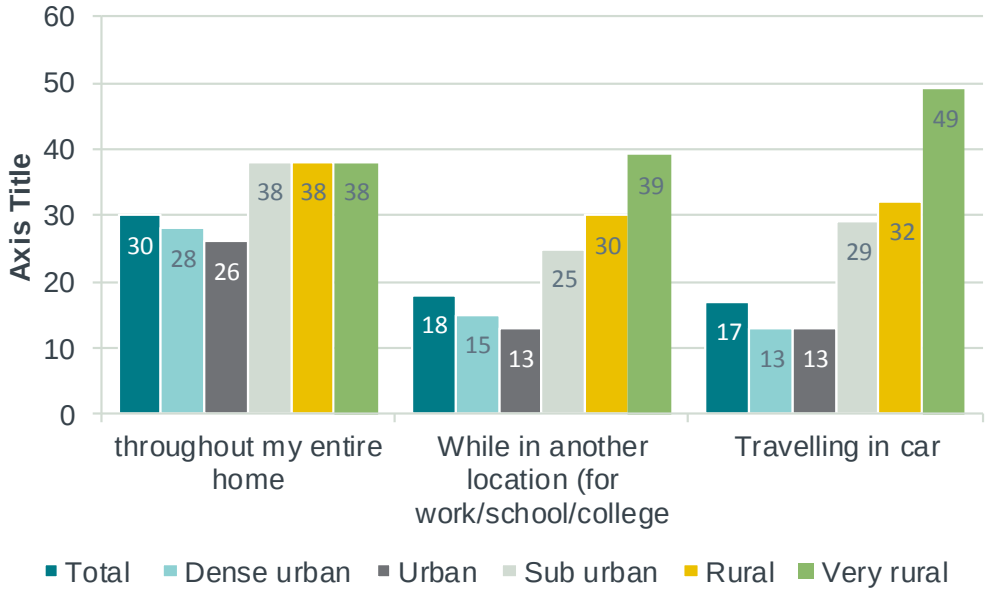
Given the variability of conditions that mobile users experience, it is not surprising that they can at times report problems with their connections. ComReg regularly surveys Irish mobile users to understand their experience of mobile performance. From these surveys it is clear that a significant minority of users report experiencing performance issues with their mobile network.

However, the proportion of users that experience performance issues increases sharply in more rural areas as there are less cell sites per km^2 and increased distances between users and those sites . While 30% of all users experienced data service issues throughout the home, this increased to 38% in suburban, rural and very rural areas. Similarly while 17% of all users reported experiencing performance issues while travelling in a car, this increases to 49% of very rural users.

[74] Mobile Consumer Experience Survey – ComReg Document 17/100a slide 42 and 45.

[75] At a fixed location the available download speed will typically depend on the specific technology used to supply the service (whether DSL, VDSL, DOCSIS cable or Fibre to the Home), and potentially (in the case of DSL and VDSL) distance from the exchange or cabinet. Therefore when selling fixed broadband at a given location the provider will provide an estimate of the likely speed of the connection.

Figure 14 Incidence of experiencing data service issues in the last month in Ireland



Source: Mobile Consumer Experience Survey ComReg 17/100a slide 52
Note: Summer 2017

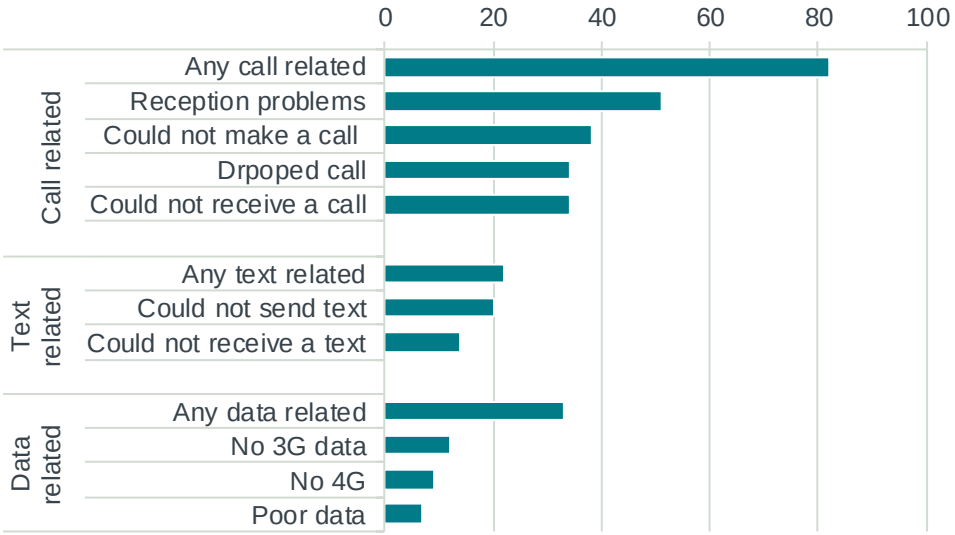
Some of the potential causes of mobile performance issues are discussed further in Section 4. The Mobile Consumer Experience Survey highlights performance in sub-urban areas as better than urban or rural locations. This likely arises for a number of reasons. Users in sub-urban areas are likely to be located nearer a mobile cell site than in rural areas; they are less likely to encounter obstacles to mobile signal (such as large buildings in urban areas or topographical features in rural areas, such as hills or trees); and cells are less likely to reach technical capacity constraints as they are in urban areas (where capacity demands are so great that technical limits are reached on the amount of capacity available).

Such performance issues are also highly frequent; of those consumers who experience poor signal within their homes, 58% of those that experience issues say these issues occur at least on a daily basis, if not several times per day[76].

The range of service issues that were reported varied (see Figure 15). Call related issues were the most widely reported, (which can be mitigated by Native Wi-Fi), though users also reported issues with texting and data. In Section 4 we set out some of the causes for service problems, and Section 7 describes the actions that all users can take to improve service.

[76] ComReg Mobile Consumer Experience Survey 2017, ComReg Document 17/100a.

Figure 15 Incidence of performance issues in mobile service (%)



Source: ComReg Mobile Consumer Experience Survey 2017, ComReg 17/100a

4 CHALLENGES IN PROVIDING CONNECTIVITY IN IRELAND

Providing connectivity in Ireland is challenging for different reasons, which we explore in this section.

- Section 4.1 describes the challenges in providing connectivity to Ireland's population.
- Section 4.2 describes why providing coverage on Ireland's extensive road network is challenging.
- Section 4.3 identifies other factors such as modern building materials (designed to meet energy efficiency goals) or older building materials (such as stone) that can also affect service performance.

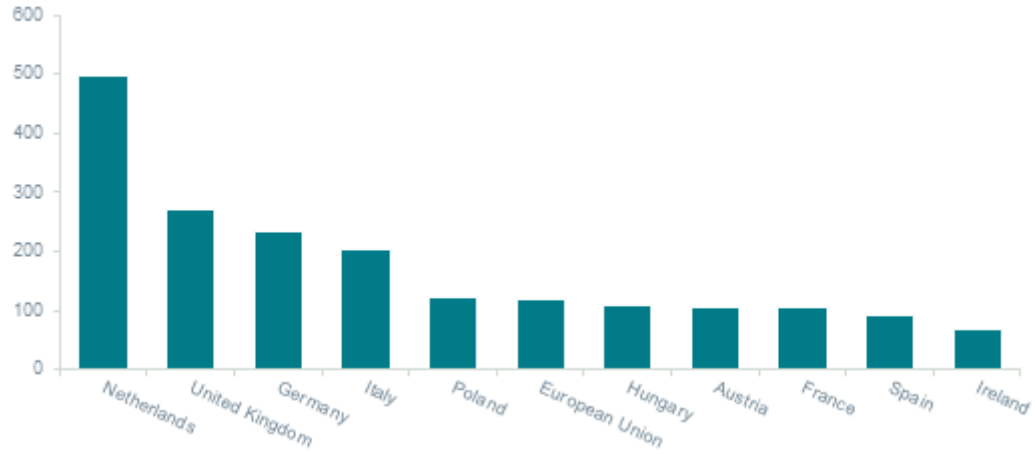
4.1 Mobile connectivity in rural areas is challenging

Areas where populations are spread across large regions pose challenges to the provision of connectivity. As a result, the relatively rural nature of Ireland means that it faces particular challenges in providing mobile connectivity services.

4.1.1 A significant proportion of the population live in rural areas

Ireland is a very rural country. The population density is markedly lower than its European counterparts: 69.3 persons per square km in Ireland compared to the European average of 117.5 persons per square km.

Figure 16 Population density (persons per square km)



Source: Eurostat

Farmland and forestry accounts for 76% of the total area of Ireland, around 5.2 million hectares. Indeed, the ratio between farmland land and the total area of Ireland is the highest in the EU[77]. This creates challenges in reaching sparsely

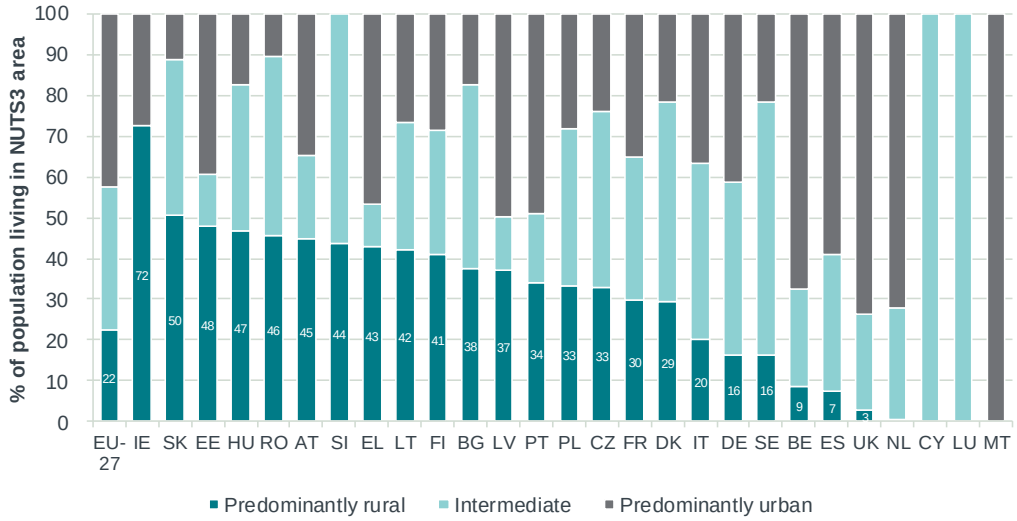
[77] Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Farm_structure_statistics

populated areas due to the high fixed costs of laying network infrastructure and maintaining it over thinly distributed populations.

Furthermore, Ireland's population is not dispersed equally. The urban population accounts for 67% of the population but this population is located in just 5% of the total area of Ireland. Alternatively, 37% of the rural population is spread across 95% of the area, with just 3% of the population located in 28% of the area of Ireland.

Of EU Member States, Ireland also has by far the highest proportion of population that live in NUTS 3 areas[78] classified as Rural. Of the eight NUTS3 regions in Ireland, only Dublin City is classified as predominantly urban, whereas the remaining seven regions are classified as predominantly rural. According to Eurostat, 72% of the Irish population live in NUTS 3 areas that are defined as predominantly rural areas. By contrast, across the EU as a whole only 22% of the population live in areas that are defined as rural regions.

Figure 17 % of population that live in a rural region



Source: Eurostat. See: http://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Urban-rural_typology_update&oldid=262364

Exacerbating the costs in providing coverage in Ireland is the prevalence of "one-off housing". One off housing describes housing developments that are single dwellings, as opposed to planned developments of multiple dwellings. According to the 2016 Census[79], 71.8% of the houses in rural areas are categorised as one-off houses[80]. This means that many households in rural areas are not in a cluster of closely located houses (in a rural village) where the economics of roll out might support incremental capacity, but instead are dispersed over a wide area.

[78] There are 8 NUTS 3 regions in Ireland. Each NUTS-3 region is classified as predominantly rural, intermediate or predominantly urban based on certain thresholds of population size and density. These thresholds are applied to combinations of grid cells of 1 km square to get a proportion of rural areas within a given NUTS-3 unit. Units where less than 20% of the population is urban are predominantly rural, those with 20%-50% rural populations are intermediate areas and the rest are predominantly urban.

[79] Source: Central Statistics Office

[80] Source: http://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/Define.asp?Maintable=E1063&Planguage=0

4.1.2 Mobile signal strength can be limited in rural areas

In order to provide mobile coverage to the large number of users that live in rural areas, mobile operators must establish a network of towers ("cell sites") which support mobile connectivity over a wide area. In rural areas, the distance between sites (the "inter-site distance" (ISD)), will be large, reflecting the low density of users. However, the farther that users are located from cell sites, the greater the scope for loss of signal strength. That is, as mobile users move farther away from the site the "signal to noise ratio" (SNR)[81] falls, which in turn means the quality or speed of connection drops. Further, mobile signal can be impacted by topography and local terrain particularly solid objects such as buildings, trees, hills, walls etc. The more obstructions there are between the base station and mobile handset, the more the signal strength is affected

Therefore, given that on average in sparsely populated rural areas, users are likely to be located farther from a cell site, it is more likely that users experience performance problems in these areas.

4.2 Ireland has an extensive road network

Consumers tend to experience poor quality mobile connectivity when travelling. Poor mobile experience can be for different reasons.

- Mobile signal strength is degraded when used within a car (since the signal needs to penetrate the glass, insulation and metal of the car);
- Signal strength is lower when users are in motion; and
- Certain topographical issues (such as deep cuttings) can prevent or degrade mobile signals from reaching users.

In combination, these factors degrade the connectivity experience. These issues are compounded in rural areas where signal strength can be lower in the first place. This is reflected in consumer experiences as reported in surveys[82]. Almost half of all survey respondents experienced data connectivity problems while travelling in the most rural areas[83]; while in other rural areas[84] around a third of users experience service issues travelling. This compares to between 13% (suburban) and 17% (urban) who experience data quality issues while travelling[85].

Ireland's extensive road network therefore presents challenges to mobile operators. Ireland's road network is extensive with 5,306 km of primary and secondary roads[86]. There is a further 91,000 km network of regional and local

[81] The SNR compares the level of a desired signal to the level of background noise. SNR is defined as the ratio of signal power to the noise power expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise.

[82] ComReg Mobile Consumer Experience Survey 2017 ComReg 18/23a. Slide 52.

[83] ComReg 18/23a defined different areas by population density. Most rural areas are defined as a population density of less than 10 inhabitants per km^2. Sample area 5.

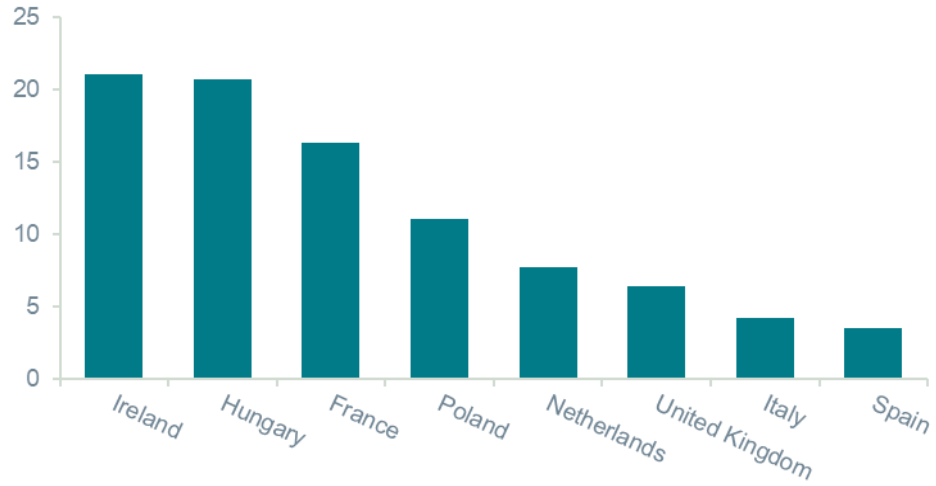
[84] Other rural areas are defined as a population density of between 50 and 10 inhabitants per km^2. Sample areas 3 and 4. ComReg 18/23a.

[85] Suburban are defined as a population density of between 50 and 10 inhabitants per km^2 (sample areas 2) and urban is defined as population density greater than 100 inhabitants per km^2 (sample areas 1). ComReg 18/23a.

[86] Source: http://www.tii.ie/roads-tolling/our-road-network/

roads[87]. The road density in Ireland, measured at 21 km per 1000 inhabitants, is one of the highest in the EU.

Figure 18 Road density (km per 1000 in habitants)



Source: Eurostat

Outside urban areas, mobile operators provide coverage in areas where their customers are located. Therefore, while they may build dedicated capacity to support connectivity on the most used roads, the sheer volume of roads (compared to users) in Ireland means that this is only economically viable on a minority of roads.

4.3 Modern building materials reduce indoor mobile signals

In addition to Ireland's rural environment and dense road network, service providers also face a number of other challenges to improving connectivity. For example, enhanced building insulation (which is important in meeting environmental goals) acts as a barrier to mobile signals and so limits indoor service quality. Modern buildings, that are designed to minimise heat loss by using certain types of insulation, often tend to increase the signal loss[88].

The increased drive to adopt more environmentally friendly building materials is driven by policy initiatives. For example, the 2012 Energy Efficiency Directive ("EED")[89] requires EU Member States to set up energy efficiency schemes. Ireland's scheme - known as "Better Energy Homes" – provides grants to support households adopt more environmentally friendly materials. The Irish government has supported this policy by updating its Building Regulations for all newly constructed houses. These changes aim to maximise heat capture and minimise

87 Source: http://www.dttas.ie/roads/english/regional-and-local-roads

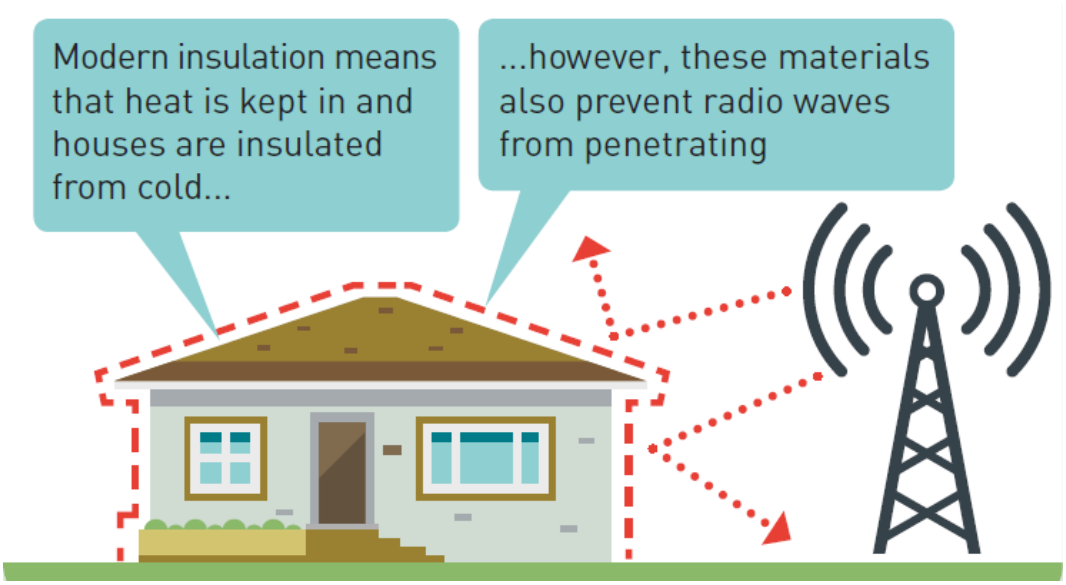
88 See for example Rodriguez Larrad, I., Nguyen, H. C., Jørgensen, N. T. K., Sørensen, T. B., & Mogensen, P. (2014). Radio Propagation into Modern Buildings: Attenuation Measurements in the Range from 800 MHz to 18 GHz. In Vehicular Technology Conference (VTC Fall), 2014 IEEE 80th (pp. 1-5). IEEE. I E V T S Vehicular Technology Conference. Proceedings, DOI: 10.1109/VTCFall.2014.6966147

89 See: http://www.seai.ie/EEOS/Energy-Efficiency-Directive-2012-27-EU.pdf

heat loss through the walls, roof and windows of modern buildings, chiefly through the use of new window, brick and insulation materials.

These modern building materials – especially those containing metals such as foil-backed thermal insulation or windows with aluminium or metallic frames - can have a significant impact on radio signals as they penetrate a building. The foil or metal layers help reduce heat loss from inside, but also 'reflect' incoming radio signals from outside (see Figure 19). (Similarly it is more difficult for mobile signals to penetrate older stone built buildings often found in rural areas.)

Figure 19 Modern building materials lower mobile signal strength



Source: Frontier

As noted in section 3.1 a significant minority of users report that they have in-home mobile performance problems. These are slightly more likely to occur for users in rural locations, but can also affect users living in dense urban areas, and suburban areas.

In areas where outdoor signal strength is not already very strong (for example in areas which are not close to a cell tower, or where there are other environmental factors affecting signal strength) the additional signal loss as a result of more environmentally friendly building materials can limit indoor connectivity performance.

The impact of building materials on signal strength has been recently examined by ComReg[90]. ComReg conducted experiments in controlled environments, which precisely measured the impact of different building materials on signal strength. The impact of each building material on signal strength was measured relative to no building material ("the reference"). The resulting difference in signal strength is measured in Decibels ("dB") which quantifies the change in signal strength. A finding of a 20 dB change represents a reduction in signal strength of 100 times;

[90] The Effect of Building Materials on Indoor Mobile Performance ComReg Document 18/73 "In carrying out the measurements, ComReg collaborated with Aalborg University and the measurement methodology was also reviewed by Queen's University Belfast"

and a 60 dB change represents a reduction in signal strength of 1,000,000 times and depending on the handset calls may begin to deteriorate or drop altogether.

ComReg found that:

- Different types of window could lead to between 15 dB and 45 dB power loss compared to the reference;
- Building insulation materials could lead to between 15 dB and 60 dB power loss compared to the reference. Insulation materials with metallic layers tended to cause significantly more attenuation compared to materials without metallic content. Plain plasterboard and several other more effective heat-insulating materials (including Isover Heatshield fibreglass insulation, Earthwool and Rockwool) also exhibited negligible signal loss compared to the reference.

Given that the extent to which these materials are used is likely to vary across different buildings, providing guaranteed indoor connectivity using mobile networks is not practical or effective since mobile signal performance will vary.

With that in mind there are a number of potential means of addressing the mobile retail consumer experience, two of which focus on the indoor connectivity issue:

- the use of mobile repeaters to address indoor connectivity issues, noting that such repeaters would have to be CE-certified and be authorised (via a licence or a licence-emption) to use the cellular radio frequencies[91]; and
- the ability to use fixed broadband connections (e.g. native Wi-Fi calling) for the provision of mobile services (both voice and data) in the home to address indoor connectivity issues.

Section 6 discusses these and other targeted actions that stakeholders can take to improve connectivity in the home.

[91] Mobile Phone Repeaters - Response to Consultation and Final Decision – published 27 June 2018.

5 COSTS OF PROVIDING MOBILE COVERAGE IN RURAL AREAS IS HIGH

The rural nature of Ireland poses challenges for providing connectivity in Ireland. Typically, many cell sites which provide coverage in rural areas will be under-utilised, since the population will be sparsely distributed across the wide area covered by a site. This means that the costs of roll out and upgrade vary for different networks and across different types of geography. In particular, costs of network roll out can rise steeply in rural areas.

The challenges of providing coverage in less densely populated areas mean that costs rise exponentially for each remaining percentage of geographic area covered, while the incremental benefits of providing coverage decline as fewer and fewer users benefit in iteratively less dense areas.[92]

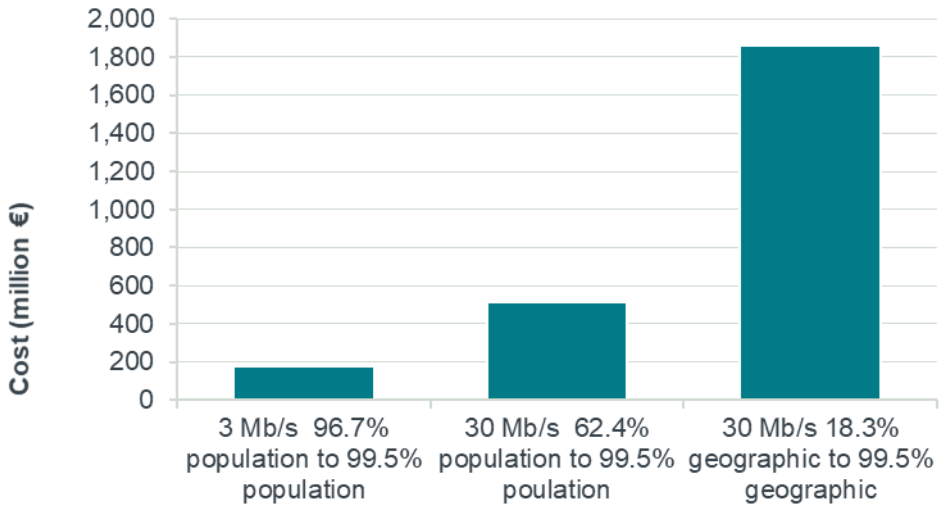
Some measures such as choice of handset or choice of network should, at the margin, improve the connectivity experience even in the most rural areas.

The making available of new spectrum (such as the 700 MHz band) could also at the margin improve the connectivity experience even in the most rural areas. However, the FMC Report estimates the incremental costs of rolling out mobile coverage (Figure 20) as follows:

- Increasing population coverage of 3 Mbps from 96.7% to 99.5% population coverage would cost €181m and require 420 new sites.
- Increasing population coverage of 30 Mbps from 62.4% to 99.5% population coverage would cost €511m and 1,466 new sites
- Increasing geographic coverage of 30 Mbps from 18.3% to 99.5% geographic coverage would cost €1,860m and 5,910 new sites.

[92] For example, as outlined in the FMC Report, the costs of increasing 30Mbps MBB population coverage from 99.0% to 99.5% is €102m, over four times greater than the cost of increasing coverage from 97.0% to 97.5%.

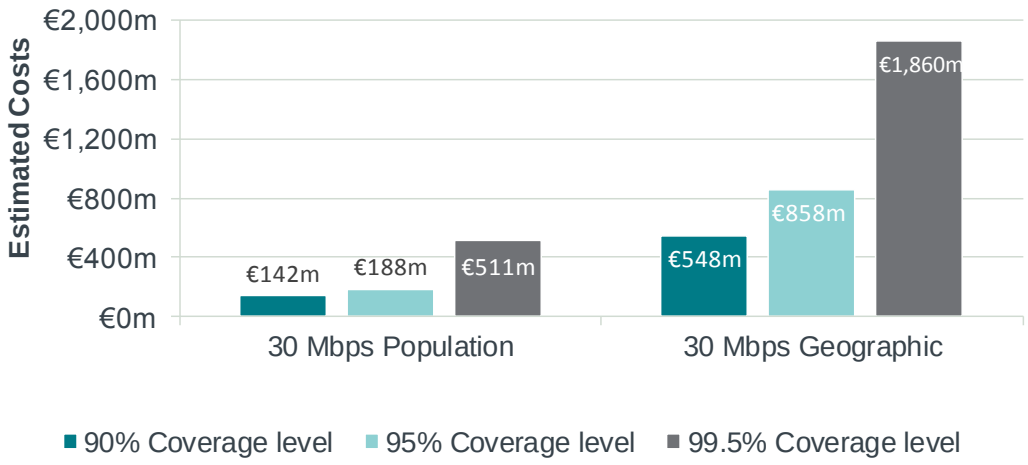
Figure 20 Cost to increase coverage from current levels



Source: FMC report

The results indicate that the costs of increasing coverage to a 99.5% coverage level depends on the coverage dimension being targeted[93] (i.e. whether population coverage or geographic coverage) and the required data speed (see Figure 21). While the costs of targeting 99.5% geographic coverage of 30 Mbps are substantial at circa €1.9bn, targeting high levels of population coverage for 30 Mbps is considerably less costly and this is likely to more commercially attractive to the market.

Figure 21 Costs of roll out at different data speeds



Source: FMC report

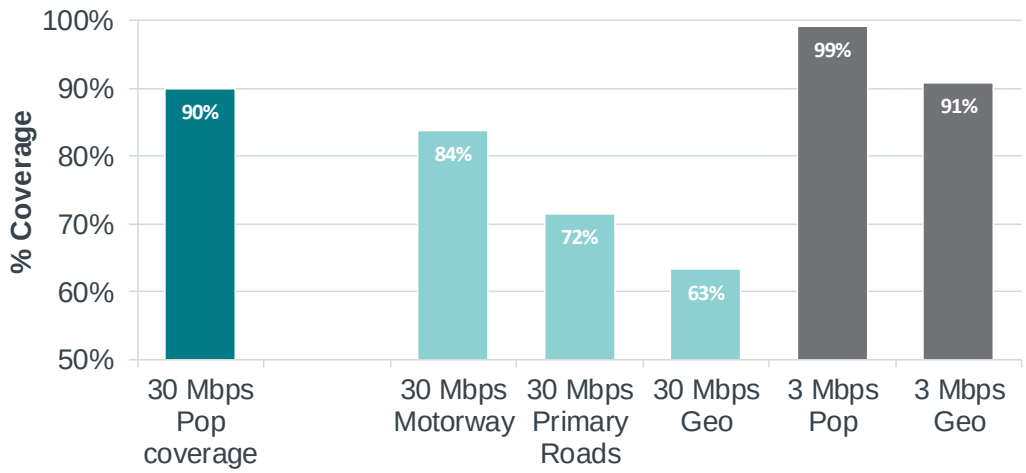
[93] Note that we assume that population coverage and geographic coverage both relate to "outdoor coverage".

In considering the results of this study, it is important to note that, **the 30 Mbps service modelled is a mobile service and is not the same level of service outlined in the NBP service requirements** which are notably higher. In particular, the NBP proposed a *minimum* level of service of 30 Mbps to premises and bidders were also requested to provide a **future proofed** network which responded to growing demand for bandwidth. This is to ensure that end users in the NBP Intervention area receive a reliable and consistent high speed broadband service indoors. The technical differences between a mobile and fixed network[94] inevitably mean that a 30 Mbps service on a mobile network is a *theoretical minimum achievable for outdoor coverage*. The actual experience could be lower and will depend on a range of issues such as the number of other users in the cell and factors that affect the quality of the mobile signal such as objects (such as buildings / walls) in between the user and the base station. Fixed networks are not affected by the same factors.

Another key result from the FMC work is that achieving high levels of population coverage leads to significant incidental coverage of geography and roads (see Figure 22). For example, if an MNO extends its network to achieve 90% population coverage of 30 Mbps, then it would (simply by virtue of where people live) incidentally achieve.

- above 80% motorway, 70% primary road and 60% geographic coverage for a 30 Mbps service; and
- above 99% population, and 90% geographic coverage for a 3 Mbps service.

Figure 22 Incidental coverage of 30 Mbps population coverage



Source: FMC report

Focusing now on the costs of extending a 30 Mbps service to a geographic coverage level of 99.5%, and assuming that this cost was recovered from customers over a seven year period the increased cost of providing coverage would add approximately 23%.[95] However, the benefits experienced by end users

[94] As discussed in section 4.

[95] Assuming costs are fully passed through, VAT of 23% is applied to the costs, current ARPU is assumed to be €25 per month. It is assumed that the costs are recovered over an 8 year asset life, at a discount rate

as a result of such an increase in availability of mobile signal would be limited since, by definition, the increase in capacity would be concentrated in areas where there were few end users.

Further, consumers' willingness to pay an additional amount per month to receive a reliable mobile phone service is marginal. Only 12% of those recently surveyed indicated they would be willing to pay an additional amount each month to receive a more reliable mobile phone service, compared to 71% who said they were not prepared to pay an extra amount.[96] Respondents to the survey claimed that they were willing to pay only €2.17 a month for a reliable voice and text quality service in their homes, and an additional €1.98 a month for a reliable data service in their homes (though this is not necessarily *in addition* to the €2.17 a month for a reliable voice and text quality).[97] This is another factor likely to influence the commercial attractiveness of extending population coverage as opposed to targeting geographic coverage.

Mobile operators are unlikely to be able to accurately set different prices (i.e. price discriminate) for customers who wish to pay for additional coverage and those who do not. Even a strategy which sought to, for example, set higher prices for rural customers (who *on average* have a higher *stated* willingness to pay for signal improvements) compared to urban customers could be impossible to implement. For example, it would likely require a coordinated approach from MNOs and some method by which to link subscription to place of residence (obviously impossible for Pay as You Go (PAYG) services). As a result, improvements in coverage and signal strength on a commercial basis are likely to continue to be gradual.

equivalent to the real pre tax WACC for mobile network operates estimated by ComReg at 8.63% (see ComReg decision D15/14) and an assumption of no growth in total subscriptions.

96 ComReg Mobile Consumer Experience Survey 2017, ComReg Document 17/100a Slide 74.

97 Furthermore responses of stated willingness to pay surveys should be treated with caution as it is well understood that responses of such surveys are typically biased upwards

6 NBP AND NETWORK UPGRADES SUPPORT INCREASING DEMAND FOR CONNECTIVITY

Ireland ranks relatively high in its connectivity (Ireland ranked 11 out of the EU 28) according to the European Union's Digital Economy and Society Index (DESI) 2018[98].

The availability of fixed networks is relatively high against most European benchmarks, although Ireland has slightly lower than average coverage of very fast (> 100 Mbps) fixed networks. However, it is likely that commercial fixed broadband investments, augmented by the NBP, will, when complete, transform the availability of very high capacity networks in Ireland. The NBP envisages that a fibre network will be rolled out to c. 540,000 premises that would not otherwise have access to high speed broadband.

Mobile operators have rolled out networks so that 99% of households have coverage of 3G and 97% of households have access to 4G.[99] However, as set out previously, some consumers experience problems with connectivity indoors where outdoor reception may be available.

Therefore, connectivity is supplied by an overlapping set of networks and from a consumers' perspective, the boundaries between networks are blurring. Consumer devices, applications and content are expected to be available across multiple networks whether fixed or mobile. However, the underlying economics mean that each network offers different capabilities and has different costs to supply connectivity capacity. Ultimately, consumers combine a mix of networks to meet their connectivity needs.

We describe below:

- In Section 6.1, the availability of fixed connectivity in Ireland;
- In Section 6.2, the availability of mobile connectivity in Ireland;
- In Section 6.3, how the NBP is expected to improve all forms of connectivity in Ireland;
- In Section 6.4, the impact that the advent of 5G services might have;
- In Section 6.5 describes how despite growing convergence between fixed and mobile networks, that there remain differences between different networks; and
- In Section 6.6, recent networks developments in Ireland.

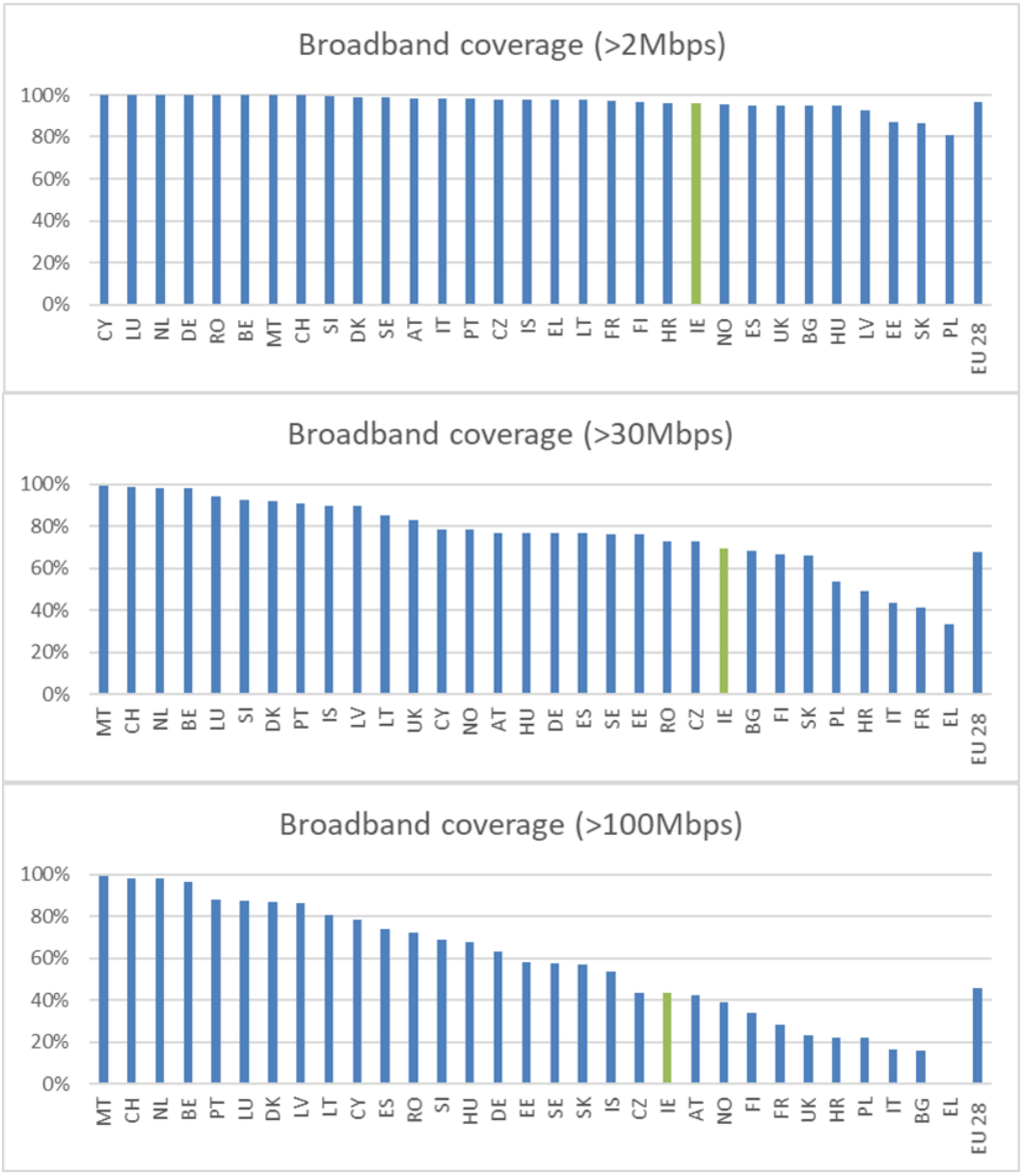
[98] Ireland ranked 11 out of 28 in the Digital Economy and Society Index (DESI) 2018, Connectivity Index. *"The connectivity dimension looks at both the demand and the supply side of fixed and mobile broadband. Under fixed broadband, it assesses the availability as well as the take-up of basic, fast (Next Generation Access – NGA providing at least 30 Mbps) and ultrafast (at least 100 Mbps) broadband and also considers the prices of retail offers. On mobile broadband, the availability of 4G and the take-up of mobile broadband are included. Digital Connectivity is considered as a social right in the EU."* The DESI is a composite index that summarised indicators on fixed and mobile connectivity, human capital, usage of internet services, integration of digital technology in businesses and digitisation in public services. On the connectivity dimension, Ireland scores well with a particularly strong score in Mobile Broadband connectivity.

[99] Digital Economy and Society Index Report, relates to 2016.

6.1 Availability of fixed connectivity

About 96% of Irish households can access speeds greater than 2 Mbps on fixed networks, 77% get above 30 Mbps and 45% have access to speeds higher than 100 Mbps. While the proportion of households that have access to at least 30 Mbps fixed broadband is broadly comparable to the EU average, Ireland lags the EU average in coverage of high speed fixed networks of greater than 100 Mbps.

Figure 23 Broadband coverage by speed in EU



Source: *Digital Economy and Society Index Report*
Note: *Relates to 2016*

Fixed telecoms networks

eir's DSL network serves 92.5% of premises, and VDSL reaches 80.6% of premises[100]. However, the inherent limitations of copper technologies[101] mean that eir's network is less able to support high bandwidth connectivity to premises in rural areas due to the longer copper loops and lower population density (which reduce incentives to upgrade networks) in those areas.

Cable networks

Cable TV networks started rolling out in the 1960s to supply TV services but have evolved to allow for the provision of internet connectivity. The Data Over Cable Systems Interface Specification (DOCSIS) enables the delivery of Internet Protocol (IP) traffic over cable TV networks with significantly higher data rates when compared to analogue modems and integrated services digital network (ISDN) links. As of May 2017, Virgin's cable network passes 856,300 homes with the DOCSIS 3.0 technology that allows top-end speeds of up to 360 Mbps[102]. According to Virgin, it plans to extend its cable network to a further 200,000 homes over the next two years.[103]

Liberty Global, Virgin Media's parent company, announced that 90% of its networks in Europe are ready for DOCSIS 3.1 deployment in 2018. However, Liberty Global does not have plans to offer DOCSIS 3.1 in the immediate term and instead will make the offer when they see demand from consumers who are willing to pay for high bandwidths.[104]

FTTH ('Fibre to the Home') networks

A number of operators have rolled out FTTH networks. FTTH is referred as the technology of transmitting data as a pulse of light along the fibre optic cable, with fibre cable laid all the way to the customer's home. Currently, fibre is replacing the traditional copper wire used in fixed telephony and DSL networks, as fibre optic cables are significantly faster and more secure compared to copper wire.

- Siro, an ESB/Vodafone joint venture, has passed over 125,000 homes with FTTH and its network is being extending further across the country.[105]

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[100] Source: European Commission, Study on broadband coverage in Europe 2016 https://ec.europa.eu/digital-single-market/en/news/study-broadband-coverage-europe-2016

[101] For example, traditional copper wire transmits data by electrical impulses, whereas alternatives such as fiber optic cable is made from fine glass fibers, which carry light impulses transmitted by an LED or laser. Fibre optic cable is also much less susceptible to noise and electromagnetic interference than copper wire. For example, copper wires can experience degradation in quality over certain distances, while this is negligible over fibre optic cable.

[102] Various DOCSIS standards have iteratively been developed to provide broadband over cable TV networks. DOCSIS 3.0 is the standard that is currently most used in Europe. DOCSIS 3.1 will provide significant improvements over the 3.0 standard. The DOCSIS 3.1 standard will enable download speeds of more than 1 Gbps (and potentially offer download speeds of multiples of 1 Gbps) as well as much greater capacity for uploading. These improvements will arise as a result of upgraded Hybrid Fibre Coaxial (cable TV) networks and upgrade consumer equipment using new standards.

[103] Source: https://www.telegeography.com/products/globalcomms/data/company-profiles/we/virgin-media-ireland-formerly-upc/company-overview.html

[104] Source: http://www.broadbandworldnews.com/author.asp?section_id=472&doc_id=740713

[105] https://switcher.ie/blog/broadband-tv-home-phone/siro-signs-20-million-contract-with-axione-and-obelisk-to-connect-10-towns-to-its-gigabit-network/

- eir has begun a programme to roll out FTTH on a commercial basis to up to 300,000 homes. These homes will not form part of the NBP intervention area provided that eir completes this roll out in accordance with commitments given to the Irish Government[106].
- ENet also has a metro fibre network (though not an FTTH network) in some areas of Ireland.[107]

Fixed Wireless Access

Fixed Wireless Access (FWA) operators provide wireless fixed broadband services to subscribers. The broadband signal is delivered via a base station and a terminal fixed to subscribers' premises. There are currently 47k FWA subscribers in Ireland. Many of these will be in rural areas where fixed broadband using DSL, cable or FTTH is not available. FWA customers make up around 3.3% of all fixed broadband subscriptions[108] and are provided by firms such as Imagine.

Other networks

In addition, satellite networks offer satellite based broadband which claims to support download speeds of 30 Mbps to the entire country (including very hard to reach rural areas)[109]. However, the high cost of launching satellite transponders and the relatively constrained capacity can mean prices are higher than other forms of fixed broadband and latency is inherently much higher.[110]

There are also a number of bespoke application specific networks used in Ireland that are not typically used directly by consumers.

[106] https://www.dccae.gov.ie/en-ie/news-and-media/press-releases/Pages/Naughten-finalizes-the-Broadband-Intervention-Map-.aspx

[107] https://www.enet.ie/news/152/138/Taoiseach-launches-enet-s-1-5M-fibre-network-in-Castlebar.html

[108] ComReg 18/20 Quarterly Key Data Report Data as of Q4 2017

[109] See for example http://irishsat.ie/broadband/ ; https://bigblu.ie/satellite-broadband/

[110] Latency refers to any of several kinds of delays typically incurred in the processing of network data. A low-latency network connection is one that experiences small delay times, while a high-latency connection suffers from long delays. For example, a high speed, high latency connection would result in a noticeable delay after clicking a link on a web page, however, after that delay the web page would start downloading and show on screen at once.

BESPOKE WIRELESS COMMUNICATIONS SYSTEMS

Some applications have specific requirements which use application specific networks. These include:

- Low Power Wide Area (LPWA) networks require low bandwidth but high coverage to support the Internet of Things (IoT) applications. IoT describes the everyday consumer devices (as well as many business devices) that will connect to the internet. Declining costs of technology and improvements in battery design mean that IoT devices can get ever smaller (and cheaper), which will rapidly increase penetration. IoT may use existing networks or use specific networks. For example, the 868 MHz band is licence exempt band suitable for IoT. Operators in Ireland have already started to support NarrowBand IoT (NBIoT) devices which uses software updates to upgrade existing networks to support high coverage for IoT services.
- Private/Professional Land Mobile Radio systems (PMR) typically can support a number of different end users. These can include the industrial sector, transportation sector (including airports and railways) and governmental sector (blue light forces, but also e.g. embassies), lifesaving services, cross border links, the energy/utilities sector (smart metering/smart grids), hotels/tourism sector, financial sector, the agricultural and forestry sector, the retail sector. Spectrum for PMR is currently concentrated in the 450-470 band.
- Programme Making and Special Events (PMSE) encompass a range of wireless services, such as wireless cameras and microphones used in the production of live theatre and concert events as well as supporting activities such as news gathering, sports events and outside broadcasts.
- Public Protection and Disaster Relief is provided in Ireland by Tetra Ireland. Communications Ltd using Terrestrial Trunked Radio (TETRA) technology in the 380-385 / 390-395 MHz frequency band. This band is harmonised by ECC Decision (08)05 for narrowband PPDR applications.

6.2 Availability of mobile network connectivity

6.2.1 Mobile networks have high coverage

97% 4G population coverage

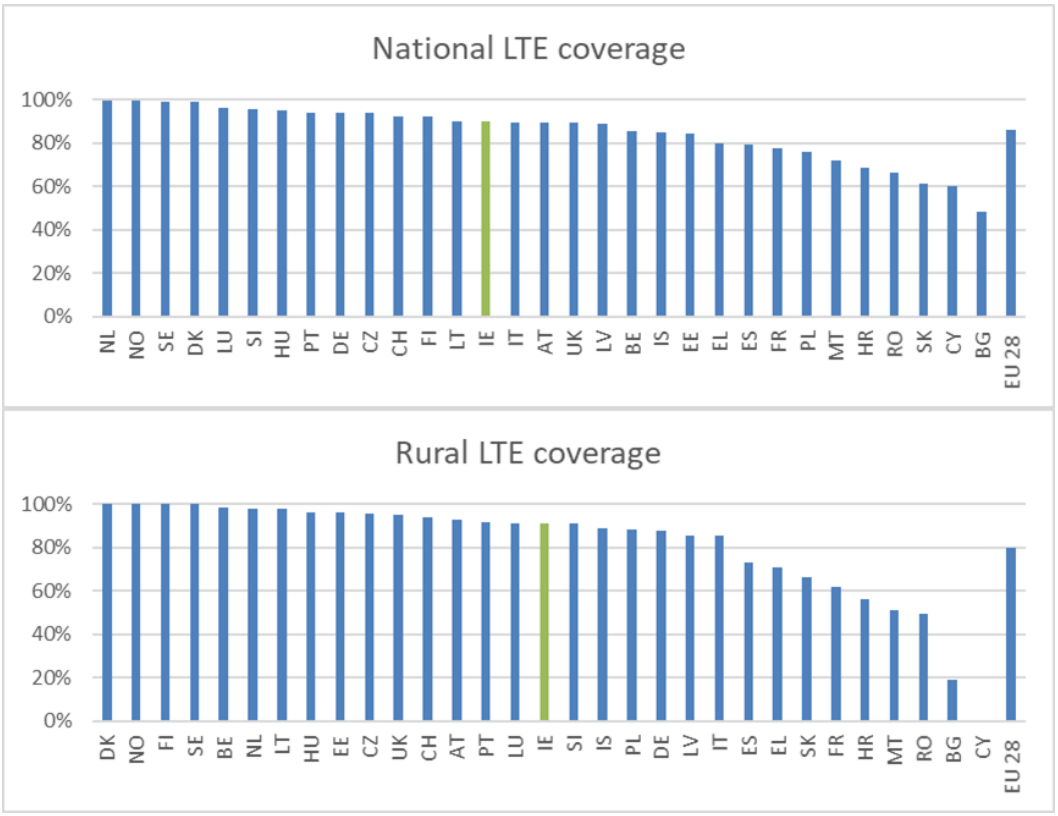
Mobile networks, originally conceived as voice networks, have adopted new standards and new technologies, together with additional spectrum released by Governments, to support data services. In recent years, operators have rolled out 3G[111] and 4G LTE. 4G LTE services were launched from 2012. In Ireland, these technologies increased availability of mobile broadband to large areas of the population previously unserved: 99% of households have out-door coverage of 3G and 97% of households live in areas with access to 4G[112].

Ireland's household coverage of 4G LTE services is slightly higher than the EU average, both nationally and in rural areas.

[111] Initially 3G was rolled out on 2,100 MHz and later using UMTS 900 technology.

[112] Digital Economy and Society Index Report, relates to 2016.

Figure 24 4G LTE coverage in Ireland



Source: Digital Economy and Society Index Report
Note: Relates to 2016 coverage

The rollout of 4G networks enabled theoretical *maximum* peak speeds of up 225 Mbps[113]. However, actual average speeds are below this level. Field work conducted by ComReg revealed that on average *actual* download speeds were 2-3 times faster on 4G LTE compared to 3G when stationary, and 5-6 times faster when mobile[114].

6.2.2 ComReg has supported operators

To support network operators and consumers in Ireland ComReg has released spectrum for mobile use and will continue to do so. This is important because incremental capacity on networks (and related bandwidth speeds that users experience) is related to the spectrum that is available to be used.

Prior to the 2012 Multi-Band Spectrum Award (MBSA), there was a total 250 MHz released for mobile, nomadic and fixed wireless services. This could potentially increase to 1,100 MHz of spectrum allocated to supporting mobile, nomadic and fixed wireless broadband services in the near to medium term[115]. In that regard, ComReg recently issued a consultation on the release of additional spectrum, and

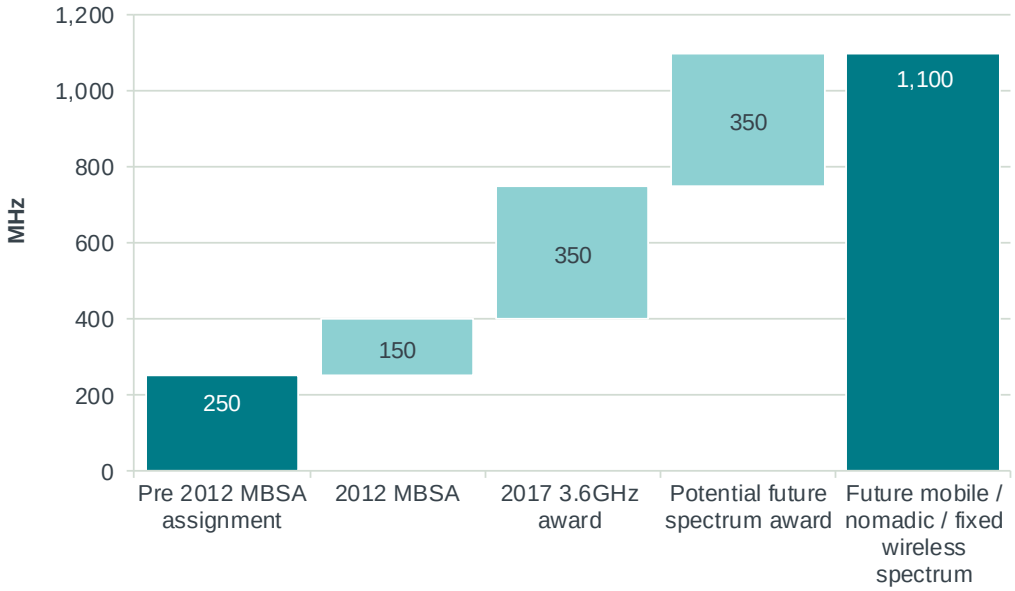
[113] Three. See: http://www.three.ie/explore/4g/

[114] When stationary 3G average speeds were between 8-8Mbps; 4G average speeds were between 4-22 Mbps. When mobile 3G average speeds were between 3-5 Mbps; 4G average speeds were 17-22 Mbps. Results were based on drive tests conducted in winter 2016. See ComReg 17/25. Results compare the average download speeds obtained for each operator on LTE and 3G networks.

[115] This relates to the total amount of harmonised radio spectrum that could be made available by ComReg should it continue to progress the proposed award discussed in ComReg Document 18/60

proposed the release of spectrum in the 700MHz, 2.1GHz, 2.3GHz, and 2.6GHz bands.[116] The spectrum bands are all EU/CEPT harmonised bands for wireless broadband. Of these bands, the 700MHz band is likely to be of most interest in Ireland in terms of providing or improving coverage, given that its strong propagation qualities support more cost-effective approaches to the coverage of distributed and rural populations.

Figure 25 Total harmonised spectrum available for mobile, nomadic and fixed wireless broadband services



Source: ComReg

6.3 National Broadband Plan (NBP)

In 2012, the Department of Communications, Energy and Natural Resources (now Department of Communications, Climate Action and Environment (DCCAE)) launched a National Broadband Plan (NBP), which would provide high speed broadband to Irish households which would not otherwise have access to this service. The plan aimed to achieve:

- 70Mbps – 100 Mbps available to at least 50% of the population with a majority having access to 100Mbps;
- At least 40 Mbps, and in many cases much faster speeds, to at least a further 20% of the population and potentially as much as 35% around smaller towns and villages; and
- A minimum of 30 Mbps available to all.

The NBP led to a tendering process to invite bids to supply the infrastructure and services necessary to meet these targets. Specifically, the project envisages roll out of a high speed broadband network which will support approximately 540,000

[116] Proposed Multi Band Spectrum Award: Preliminary consultation on which spectrum bands to award ComReg Document 18/60.

premises in rural areas which otherwise would not have access to high speed broadband[117].

While the DCCAE did not specify the technology that will be used, it has stated that the bidders[118] to the tender process have indicated they are intending to use a Fibre to the Home (FTTH) service. [119]

NBP will be primarily a wholesale network that is available to Retail Service Providers to supply services to members of the public or to businesses. Once the network is rolled out, end users will be able to acquire high speed broadband services (with a download speed of at least 30 Mbps[120]) from a Retail Service Provider.

After the implementation period, the combination of the NBP, and incremental rollout of fibre by eir, would mean that all Irish households should have access to a high speed fixed broadband connection (with a minimum download speed of 30 Mbps but in many cases upwards of 100 Mbps[121]). As noted below, this will have the added benefit of providing a highly effective in supporting solutions which mitigate indoor mobile voice connectivity problems, which was a significant issues raised by respondents to the Mobile Consumer Experience Survey.

The NBP will bring other benefits. The implied "densification" of fibre networks (i.e. much greater availability of fibre and increase in the volume of areas within easy reach of fibre networks) creates synergies with other networks. It means the costs of installing mobile networks (or other wireless networks) will fall in areas where they can utilise new fibre connections installed as part of NBP. For example, the costs of providing backhaul to rural base stations is lower in the intervention area as a result of NBP.

6.4 New 5G networks will support new services as demand evolves

5G is a new mobile standard that will offer improvements and new functionality compared to current 4G standards. There remains a degree of uncertainty in how 5G will be used and its capabilities. However, it is likely to offer a number of features.

- 5G will support an iterative improvement in speed and performance (over 4G) in most areas where it is rolled out. 5G is designed to work with 4G standards which means that the available spectrum will increase, which could lead to

[117] https://www.oireachtas.ie/en/debates/question/2018-02-13/554/#pq-answers

[118] There is only one remaining bidder in the tender process.

[119] Note that the DCCAE does not specify the technology. Nonetheless it notes that *"Until a contract is signed we can't say exactly how the service will be delivered. However, bidders have indicated they are intending to use a Fibre to the Home(FTTH) service."* https://www.dccae.gov.ie/en-ie/communications/topics/Broadband/national-broadband-plan/frequently-asked-questions/Pages/Amber.aspx

[120] Other technical requirements include (1) minimum of 6Mbps upload or twice the maximum upload speed of existing broadband in the intervention area, whichever is greater, (2) Latency (one-way) and Jitter – no more than 25 milliseconds, (3) Packet loss – not more than 0.1%, (4) Service availability – at least 99.95% of the time.

[121] As noted, while the NBP tender process specified a minimum download of 30 Mbps, the DCCAE noted that bidders to the programme have indicated they would use FTTH. See footnote 120.

iteratively higher speeds. However, since in most areas 5G is likely to use similar low frequency spectrum as 4G[122] it would not of itself be expected to increase coverage

- In dense urban areas 5G networks will support very fast download speeds. New radio technologies concentrate on much higher frequencies ('millimetre waves' such as the 26 GHz band) which could support very high capacities and speeds over relatively short distances. This could allow very high capacity, and high bandwidth services, in certain areas. Alternatively, it could support very high capacity services at events such as sports matches or live music events where tens of thousands gather in one place. However, given the costs in installing and providing backhaul for the many new micro-cells that would support these services, it is expected that these would be limited to specific areas of very high demand.
- The use of high frequency spectrum with 5G standards could be used to support FWA networks which offer enhanced capabilities over existing FWA networks.
- 5G has been designed to support Internet of Things applications. These could support automotive applications such as assisted or autonomous applications (enabled by vehicle to vehicle communication); or displays with Augmented Reality.
- Operators can offer specific new network services. Networks will be able to use 5G standards to virtually "slice" capacity which can be used for software defined networks (SDNs) to provide greater flexibility for users and support specified network characteristics (very high capacity, very high speed or very low latency).

Ultimately, in the near to medium term, consumers and operators are likely to focus on those areas of mass market demand around supporting continued roll out and improvement in performance of existing networks. As new commercial strategies which rely on 5G technologies evolve, operators will start to roll out the new network technology to meet demand. However, given the current uncertainty over the final technical standards and the potential future rollout that may be required, the connectivity impact of 5G in Ireland, in the near term (to mid-2020), is likely to be minimal.

[122] 5G could be offered in the 700 MHz band for example, adjacent to the 800 MHz band used for 4G.

6.5 Despite the convergence of fixed and mobile networks there remain differences in their capabilities

As noted in section 2.3, from a consumer's perspective, there is less differentiation between fixed and mobile networks.

90%

Data carried on fixed networks, only 10% carried on mobile networks.

First, as noted above consumers now expect to be able to access services on *all* their devices, whether at home, leisure or travelling. The devices we use are technology agnostic and are designed to roam between networks. Second, the "cloud" is increasingly where we store data, software or applications. Third, fixed networks have evolved to support forms of mobility.

However, there are differences between fixed and mobile networks. These differences explain why 90% of all data carried on telecommunications networks in Ireland is carried on fixed networks. Fixed networks offer dedicated capacity to a fixed location whereas mobile networks offer shared capacity where users can roam from cell to cell. This means that capacity in mobile networks is, at peak times in some locations, more scarce since it is shared with other users. This affects the cost and available capacity on the networks. For this reason, devices or software applications are often designed to reflect the different capacity available on fixed and mobile networks. For example, device Operating System updates are set to download from the cloud when connected to fixed networks. Devices will be continuously scanning for available networks and will typically prioritise the networks with capacity and strongest signal. If a Wi-Fi network is available the device will prioritise this network to download data, given the likely greater capacity and lower cost.

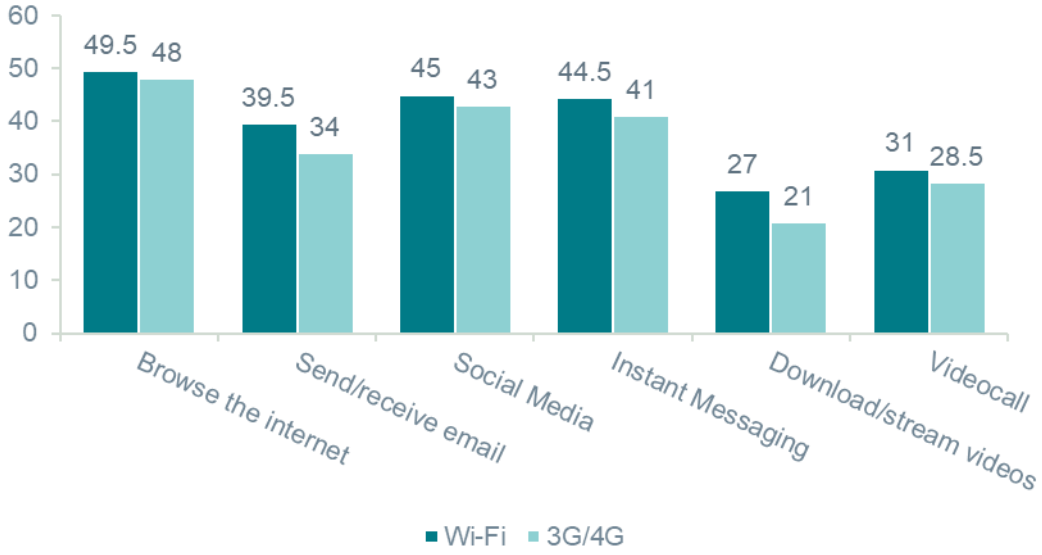
Consumers may also adjust their behaviour in response to differences in costs of data. For example, on fixed networks eir and Virgin Media offer unlimited data caps. In contrast, eir's, and Vodafone's mobile plans are priced to offer different tiered caps (while Three's "unlimited" mobile plan is capped at 750GB per month). Consumers therefore adjust their behaviour to avoid using up their data allowance (such as adjusting settings on their device[123] or using a data tracker which is built into operating systems; or downloading content from a fixed connection onto their device to watch while travelling).

For example, a recent survey for ComReg found that while consumers make use of both fixed and mobile networks they are more likely to download or stream content over Wi-Fi networks compared to mobile networks (see Figure 26). 27% of survey respondents report that they stream or download content over Wi-Fi at least two or three times a week; whereas 21% report streaming or downloading video content on mobile networks at least two or three times a week. Furthermore, it is

[123] See for example: http://www.thejournal.ie/data-usage-control-2020712-Apr2015/

notable that, despite the fact that mobile penetration is near ubiquitous, 90% of all data is carried on fixed networks compared to 10% on mobile networks.

Figure 26 % Users who access online Services 2-3 times a week or more

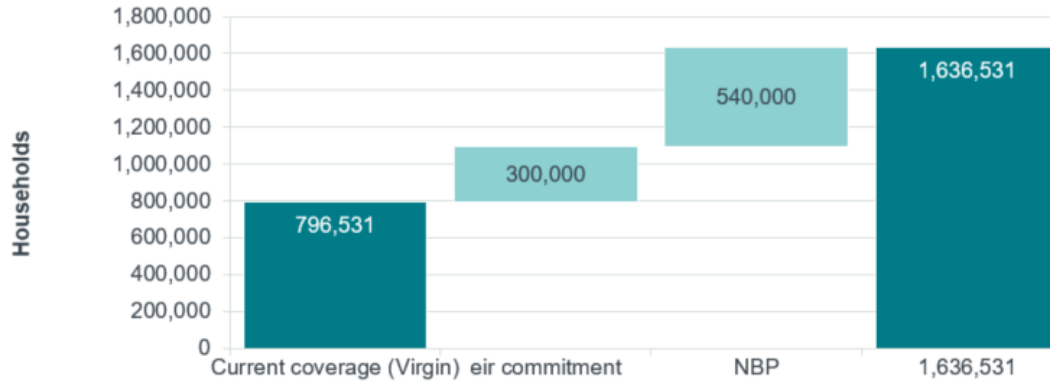


Source: Ireland Communications Survey 2017, ComReg 18/23a

6.6 Summary of network developments in Ireland

According to the European Union's Digital Economy and Society Index (DESI) 2018, Ireland ranks relatively well in terms of its connectivity. Furthermore, actions are on-going to improve fixed connectivity in rural areas. Once completed, the NBP is expected to result in all rural Irish households having access to high speed broadband. 4G Mobile networks have rolled out to almost all premises such that coverage of 4G services is now 97% of households.

Figure 27 Expected coverage of fast broadband (>30 Mbps)



Source: Frontier

Note: while the NBP tender process specified a minimum download of 30 Mbps, the DCCAE noted that bidders to the programme have indicated they would use FTTH. See footnote 129.

However, as noted in section 3.1 the inherent limitations of mobile technology mean that users can sometimes experience connectivity service problems, particularly in rural areas and when travelling. Given the varying capabilities of

networks, consumers use a patchwork of different networks throughout their day, even if they do so in most cases without consciously realising.

End users will, typically, not have a detailed understanding of the technological differences in capacities, capabilities and availability of different network resources. However, they may have visibility of the cost differential in downloading over a fixed network compared to a mobile network. Consumers will also most likely appreciate some of the limitations of mobile networks: that they generally offer lower speed connectivity than fixed networks, with quality of service depending on factors such as whether the user is inside or outside, and therefore adjust their behaviour accordingly.

Future improvements to networks

Network operators are also likely to deliver significant connectivity improvements in the period following the assignment of rights of use to the candidate bands. As observed in the 'FMC' Report[124], MNOs are likely to extend coverage to over 98% population in the period up to 2020. After 2020, a large proportion of consumers across the country can expect to see significant improvements in their mobile connectivity experience. From mid-2020, the commercial extension of mobile networks is likely to switch to a focus on extending higher-speed connectivity (e.g. minimum 30 Mbps population coverage) to larger parts of the population. This expansion will be enabled as more spectrum becomes available. The higher volume of spectrum will enable three-band Carrier Aggregation (a technology that will reduce the cost of high-speed connectivity).

[124] ComReg Document 18/103c Section 5.5

7 ACTIONS TO IMPROVE CONNECTIVITY

Current connectivity levels in Ireland are good by international standards. For example, despite the challenges set out in section 4 Ireland scores well in the European Union DESI index and Ireland's fixed broadband connectivity reaches currently almost all homes, even though high speed fixed broadband is less available in rural areas.

In coming years fixed connectivity in rural and semi-rural areas should significantly improve as the NBP and planned developments by eir, are expected to together roll out fibre to 840,00 of the most rural areas in Ireland (approximately 47% of premises).

As regards mobile services, operators already provide 4G coverage to 97% of premises and higher speed broadband (30 Mbps) is potentially likely to be rolled out to a significant proportion of the population following the assignment of the candidate bands for wireless broadband. While 5G will provide speed and capacity improvements in urban areas (where high frequency spectrum can be used) and will provide an incremental improvement in speed and capacity in other areas as it is gradually rolled out, it will not of itself improve coverage or overcome the challenges outlined

In addition to this ongoing public intervention stakeholders (**Government, End users, ComReg and Industry**) can act in mutually supportive ways to further improve consumers' connectivity experience. In particular, there are a number of bottlenecks and inefficiencies and resource restraints that are currently preventing connectivity in Ireland reaching its full potential. Better coordination and the removal of bottlenecks that create inefficiencies could deliver some of the improvements required by society.

These complementary actions and strategies are already being adopted, and others which can be adopted in the future can enhance the connectivity experience in a targeted and proportionate approach. For example, there are a range of measures which, in combination, could mitigate many existing connectivity issues (such as in-building connectivity in rural areas). However, providing full geographic coverage (to erect and maintain under-utilised cell sites), to all under-populated areas is necessarily very costly, with limited associated benefits. Therefore while there are a range of measures that will iteratively improve the connectivity experience in the most rural areas (choice of handset, choice of network operator, and roll out of new spectrum bands such as the 700 MHz band), it is likely that the connectivity experience outdoors in the most rural, unpopulated areas, will never be the same as in more densely populated areas.

The stakeholders and the key contributions to improving connectivity are outlined below.

7.1 All stakeholders have a role in enabling connectivity

The challenges in providing connectivity mean all stakeholders have a role in ensuring that end users can achieve their optimal connectivity given their varying demands and different challenges. Users, policy makers, device manufacturers and other stakeholders can *all* take action that can improve connectivity.

The remaining sections of this report summarises some of the actions that different parties are taking or can take to support connectivity needs in Ireland.

7.1.1 Government

Government departments and agencies are central to reducing bottlenecks and creating efficiencies in the delivery of services. It is also best placed to lead interventions in those areas where commercial operators are unlikely to provide services. In that regard, the Government's role includes the following.

National Broadband Plan

The **NBP** is a key infrastructural project and its stated ambition to deliver high speed broadband services to all businesses and households in Ireland that would not otherwise have such access is key to the future provision of connectivity in Ireland. This project is intended to bring fibre-based connectivity to c. 540,000 premises. It also underpins much of the connectivity improvements that can be taken by consumers individually and is essential to providing an effective solution to indoor voice and data connectivity.

Mobile Broadband Taskforce

The Government has instituted the **Mobile Broadband Taskforce** ('MBT') to provide identify constraints which can impede connectivity, recommend policy solutions and coordinate actions. The MBT's activities are therefore important in removing bottlenecks and improving efficiency. These include the following.

- Reducing the cost and streamlining planning processes for the deployment of telecommunications infrastructure (Actions 7 – 11 MBT).
- Install ducting on new national primary/secondary roads (Action 6 MBT).
- Develop and publish a policy for all local authorities around access to and use of state infrastructure (Action 18 MBT)

The MBT publishes quarterly update reports, which have highlighted the following progress.[125]

- Motorway ducting works have been completed on 80km of the M7/M8. In addition, ducting work has been completed on 14km of the N25 in Cork.

[125] DCCAE (2017), 'Mobile Phone and Broadband Taskforce: Quarterly Progress Report—Q3 2017';https://www.dccae.gov.ie/documents/Taskforce Q3 Progress Report.pdf Government of Ireland (2018), 'Mobile Phone & Broadband Taskforce: Quarterly Progress Report Q1 2018'.

- From December 2017 all new major road schemes and minor realignment schemes on two lane national roads will have ducting installed in the verges.
- Legislation on Revised Exempted Developments has been signed into law.[126]

Furthermore, progress is being made in the following work in an effort to remedy certain blackspot areas of the country.

- Local authorities will map local mobile phone black spots. The information received will be collated and used as a basis to further engage with the MNOs (Action 17).
- The DCCAE has set about establishing a focus group to examine the issue of coverage and coverage expectations. It is hoped that the focus group will identify specific categories of locations where high-quality mobile coverage should be available (Action 40).

Connecting Europe Broadband Fund

The **Connecting Europe Broadband Fund** targets black spots in less populated and rural areas, providing a source of finance where commercial operators don't provide connectivity. [127]

7.1.2 End users

Many end users do not realise that there are many minor often low-cost actions which can improve their connectivity experience. These are often not implemented because consumers can face behavioural barriers or are unaware that such measures are available to them. Such measures are available to end users and makes the delivery of services more efficient and improves their connectivity experience.

Choice of mobile handset

The choice of **mobile handset** can significantly affect the connectivity experience.

Research conducted by ComReg on mobile handset performance[128] for voice suggests variation in performance of up to 14 dB between handsets which means that some handsets have significantly poorer reception than others (ComReg has published a similar report for data).

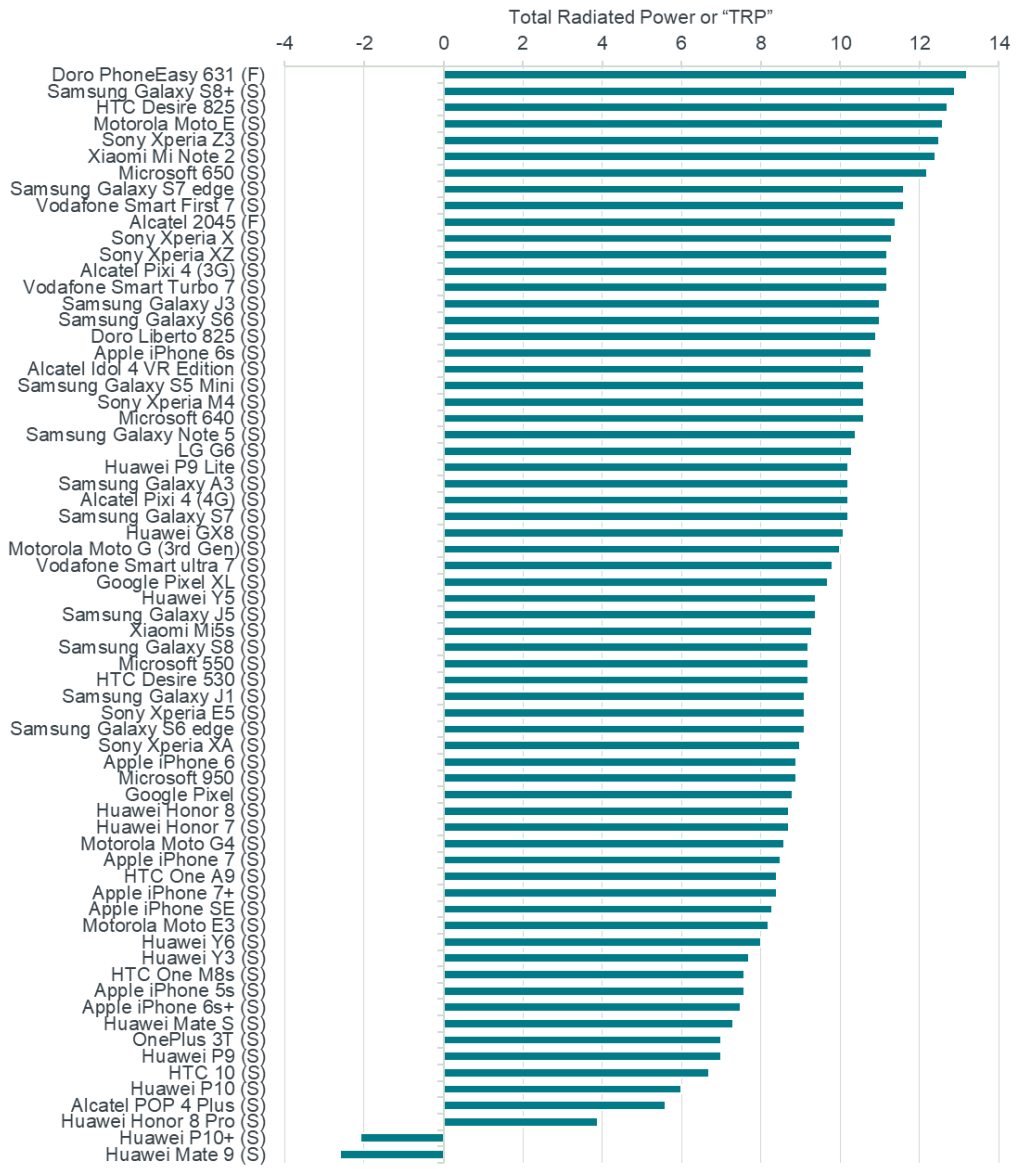
ComReg's tests measure the signal strength of a variety of handsets (as measured by Total Radiated Power or "TRP" see Figure 28 for an explanation). The results are likely to vary for each handset depending on the specific service tested (whether voice or data) and the specific band and technology being tested, therefore these results are provided for illustrative purposes only. However, as the ComReg document notes, there is significant variation in the capabilities of different handsets.

[126] The Planning and Development (Amendment) (No.3) Regulations 2018, 8 February 2018. Available at: http://opac.oireachtas.ie/AWData/Library3/HPLGdoclaid131217c_103054.pdf, accessed 23 July.

[127] https://ec.europa.eu/commission/news/investment-plan-first-eu-fund-fully-dedicated-broadband-infrastructure-unlock-least-eu1-billion-over-5-years-2018-jun-27_en

[128] Mobile Handset Performance (Voice) ComReg Document 18/05.

Figure 28 Relative performance of selected handsets, voice, UMTS 900



Source: *Mobile Handset Performance (Voice) ComReg Document 18/05*

Note: *Handset transmit performance is determined by measuring the total power radiated by an antenna over a three-dimensional sphere when connected to a transmitter – this is referred to as the Total Radiated Power or "TRP". The higher the TRP measurement, the stronger the uplink connection between the mobile handset and the mobile network. And the stronger the uplink connection, the better the experience of the user should be in the quality of mobile voice calls.*

Given the wide variety in the signal performance of different handsets, users that live in areas where signal strength is more marginal could potentially significantly improve their connectivity experience by changing their handset.

Choice of mobile operator

The choice of **mobile operator** can significantly affect the connectivity experience. Mobile networks compete with each other across a number of dimensions including in the coverage and availability of services available to consumers. For this reason the signal strength available at a given location will vary with the choice of mobile

network. ComReg provides information and advice to consumers which explains how and why mobile signal strength varies in different areas[129]. It has provided access to an online tool[130] which enables consumers to search maps to find the details of the mobile masts throughout Ireland. ComReg notes that the tool can be used to determine the MNO with the mobile site closest to any consumer's home or office.

Research conducted by ComReg[131] shows that nearly half of all consumers who switched mobile operator experienced improved mobile coverage compared to just 3% who indicated that it had worsened.

Currently not all mobile operators offer native **Wi-Fi calling**. Consumers could consider Wi-Fi calling as important competitive differentiator when choosing a service provider.

Use of mobile phone repeaters

Consumers should also consider the use of **mobile phone repeaters** in areas where connectivity is poor in and around a household and a reliable internet connection is not present. ComReg has put in place licence exemption arrangements for the general usage of these devices.[132]

Consumers will have the option of installing a repeater which can be used with a single operator, or one that can be used with any operator. This is a licence exemption that does not require MNO approval. The cost of the repeaters could be around €200-€300 which would support enhanced mobile signal for all users within the home.

Use of native Wi-Fi

Native Wi-Fi describes the use of fixed Wi-Fi networks to make calls on a mobile device using a mobile subscription. Consumers to make/receive phone calls and text messages from their Native Wi-Fi enabled mobile phone, where mobile coverage is not sufficient, by using an existing Wi-Fi network. Native Wi-Fi consumers can thus use their enabled phones and existing mobile phone number to connect via the Wi-Fi in their homes to the operator provided voice service, to provide for a higher-quality calling.

The use of Native Wi-Fi would represent a significant improvement in the making and receiving of indoor voice calls, which was a particular problem raised in the mobile consumer experience survey.

However, in order to use such a service, a number developments are necessary.

- Network operators have to make the necessary investments to support it on their network. Currently, in Ireland only eir offers Native Wi-Fi. ComReg is actively encouraging all mobile service providers to follow suit and notes that

[129] See: https://www.comreg.ie/consumer-information/mobile-phone/service-issues-2/

[130] See : http://siteviewer.comreg.ie/#explore

[131] Mobile Consumer Experience Survey – ComReg Document 17/100a.

[132] Mobile Phone Repeaters - Response to Consultation and Final Decision ComReg Document 18/58.

Vodafone plans to launch Native Wi-Fi during 2018[133], which will provide a similar service for Vodafone customers;

- Consumers require Native-Wi-Fi enabled phones. Currently, 22% of all mobile phones are 3 years old or more, rising to 34% in more rural areas.[134] Such phones are unlikely to be Native Wi-Fi enabled.[135] However, this is likely to change as devices are upgraded (i.e. the natural replacement cycle of phones should allow most consumers to be able to benefit from Native Wi-Fi in a cost effective manner).
- While the quality of native Wi-Fi calling varies dependent on the available internet connection, native Wi-Fi calling does not specifically require a "fast" internet connection (i.e. 30 Mbps). The minimum speed required is around 1 Mbps[136]. 96% of Irish households can access speeds greater than 2 Mbps on fixed networks speed. Despite this, the effectiveness of Wi-Fi calling is expected to continue to improve with rollout of minimum 30 Mbps from operators or through the NBP.

7.1.3 ComReg

ComReg continues to implement a number of measures which should provide improve the efficiency of contribute to improving the connectivity experience.

- Recently published a Technical Report into **mobile handset voice performance**[137] and **mobile handset data performance**.[138] The next report will provide results in relation to data and updates will be provided at regular intervals.
- Recently published its report on 'The Effect of **Building Materials** on Indoor Mobile Performance'[139]. It will continue to examine the overall effect of building materials and will consider how to best establish the aggregate effect on signal propagation.
- Provides **information to consumers and industry** including price comparisons[140]; advice on mobile service issues[141];
- **Conducts research** on mobile phone user experiences and perceptions[142] and telecommunications generally in order to inform itself and other stakeholders of the issues faced by end-users.

133 https://www.siliconrepublic.com/comms/vodafone-voice-lte-wifi

134 Mobile Consumer Experience Survey – ComReg Document 17/100a Slide 34,

135 For example, certain models on the Apple or Android platforms are not Wi-Fi calling enabled. For example, to use Wi-Fi Calling using the Apple platform an iPhone 5c or later is required on a supported Mobile Operator.

136 https://www.telus.com/en/bc/support/article/wifi-calling-faq

137 Mobile Handset Performance – Voice ComReg Document 18/05

138 Mobile Handset Performance – Data ComReg Document 18/84

139 The Effect of Building Materials on Indoor Mobile Performance ComReg Document 18/73.

140 https://www.comreg.ie/compare/#/services

141 https://www.comreg.ie/consumer-information/mobile-phone/service-issues-2/

142 https://www.comreg.ie/comreg-publishes-results-irish-mobile-phone-user-experiences-perceptions-national-survey/

- **Release additional spectrum** to support the increased demand for connectivity. ComReg's preliminary consultation on which spectrum bands to award in the upcoming multi band spectrum award provides for the spectrum resource assigned to mobile to increase to over 1,145 MHz. This includes the proposed assignment of the 700 MHz band which is suitable for wide area coverage.
- Intends to generate **a national coverage map** by the end of 2018 from comprehensive data, including data provided by operators and made this available on its consumer website.
- Consider **coverage and rollout obligations** as part of the next multi-band spectrum award to provide for the efficient use of the radio spectrum and promote competition to the benefit of consumers. DotEcon has set out the key considerations in designing a set of coverage obligations that result in socially optimum coverage levels,[143] published in tandem with this report. ComReg could also consider attaching licence conditions related to the provision of native Wi-Fi.
- ComReg will continue with its programme of Bi- Annual Drive Testing - Assessment of Mobile Network Operators' **Compliance with Licence Obligations** (Coverage).

7.1.4 Network operators and equipment manufacturers

There are a number of actions that can be taken by industry (network operators and equipment manufacturers) to improve connectivity and maximise the extent to which end users, in their own right, can support their connectivity experience thereby improving the efficiency of how existing networks deliver the optimum experience.

Network upgrades

Network operators will continue to **upgrade networks** and build capacity in capacity constrained areas. The 'FMC' Report estimates that operators are currently providing 96.7% of the population with 3 Mbps and voice coverage. Operators are likely to continue rolling out services commercially to serve large proportions of the population.

- 85-90% population coverage (30 Mbps) up to 2024.
- 77 – 84% motorway coverage (30 Mbps and voice) and 95% of primary road coverage (3mbps + Voice) coverage by 2023-2024.

Low Power Wide Area Networks

Operators have adopted new networks for specific uses such as **Low Power Wide Area Networks** (LPWAN) specifically to support Narrowband IoT (NBIoT)

[143] ComReg Document 18/103d

devices[144]. Such technologies are also available in licence-exempt spectrum, meaning that end-users can deploy their own IoT network.

Distribute and provide information on signal performance of handsets

Operators and handset manufacturers play a role in distributing **high reception handsets.** Handset manufacturers and mobile handset retailers could **better inform customers** of the importance of handset signal performance and benefit of Native Wi-Fi (for example providing point-of-sale advice).

Support for Native Wi-Fi

As noted above, operators can **prioritise the introduction of Native Wi-Fi** (Wi-Fi calling) which can mitigate indoor connectivity problems. For example, eir launched its service in 2017 and is the only Irish mobile network operator (MNO) to have rolled out native Wi-Fi calling on its network. eir notes that it is currently adding additional supported devices to extend the reach of the service.[145] However, we understand that Vodafone plans to launch Native Wi-Fi during 2018, which it seems will provide a similar service for Vodafone customers.

7.2 Understanding the impact on end users

We have created a number of user profiles which illustrate the different demands for connectivity in Ireland, the challenges faced in meeting their connectivity needs and the actions that stakeholders can take to improve connectivity performance.

[144] See Vodafone for example. http://www.vodafone.com/business/news-and-insights/press-release/vodafone-is-first-to-announce-nb-iot-launch-markets

[145] See: https://www.eir.ie/wificalling/

Figure 29 User profiles

Aileen Murphy Is elderly, and lives near Tranmore in the south of Ireland, in a purpose built "one off" house. She lives with her husband and relies on connectivity to stay in touch with family and friends.

She uses voice calls on her fixed phone and mobile, as well as VoIP, and video calling to stay in touch with grandchildren. She also uses social media to share pictures with her family.

Aileen's indoor mobile signal is poor and currently only typically gets a maximum of 5 - 10 Mb/s from her fixed broadband connection.

Commentary:
Use of VoIP, messaging and video calling is common across the whole population including the over 65s. On average every day at least over 65s use their mobile network: 30% browse the internet, 27% use social media, 16 % use Instant messaging, 24% send/receive emails, 14% use video calling and 3% use streaming services. Aileen's fixed connection is sufficient for VoIP and messaging, though sometimes for video calling quality can be poor.
The strong insulation in the walls and windows of her house mean that her indoor signal is poor which means that mobile calls drop when she uses her mobile indoors and sometimes cannot receive a good data signal.

Potential solutions

- The NBP will enable fast broadband for almost all.
- Mobile repeater could provide enhanced inbuilding coverage. ComReg recently published its statement permitting use of repeaters.
- Native Wi-Fi calling using the fixed broadband network. Mobile operators offer Native Wi-Fi on some handsets.

Mary and Patrick Walsh live with their three teenage children in Blackrock in Dublin.

Patrick uses his smartphone for browsing the internet, using social media, instant messaging and accessing his email. He also needs mobile connectivity to stay in touch with work when travelling.

At home the family use VoD services such as Netflix (sometimes with four different users at once) as well as online gaming.

Commentary:
The Walsh family need good connectivity at home and therefore subscribe to a 100Mb/s VDSL service from eir. Though faster services from Virgin Media are also available for example Virgin Media's HFC (Hybrid fiber-coaxial) network, capable of offering speeds up to 360 Mbps, passed a total of 896,4000 premises at the end of March 2018. Even with the demand from multiple household users, the available capacity is sufficient for all their needs.
Mobile performance problems can occur when travelling. Signal loss is experienced on parts of the road and rail network particularly in more rural areas. While loss of signal when travelling is rare in urban areas (only 13% of urban users report loss of data signal) it is much higher in rural areas (49% of users in the most rural areas report loss of signal when travelling in a car or bus).

Potential solutions

- Changing the handset might improve the signal strength which would improve connectivity when travelling.
- ComReg publishes information road coverage for major roads across Ireland.

Sean and Deirdre Lynch live with their two young children in Galway in the west of Ireland. Sean and Deirdre own a B&B.

They need fixed and mobile connectivity to support their B&B business (to take bookings and provide information).

As they live in an old stone building they currently have poor mobile indoor signal. Their fixed broadband connection is relatively slow and it does not support their guests who have come to expect good Wi-Fi when on holiday.

Commentary:
The Lynch family need good connectivity at home to support their B&B business. They rely on a mix of (slow) fixed DSL broadband (with a maximum speed of 5 Mb/s). In Ireland 23% of households have access to a fixed connection with a maximum speed of less than 30 Mb/s and 4% of households do not have a connection greater than 2Mb/s. However, these speeds are sufficient to support Native Wi-Fi calling.
Mobile performance problems are exacerbated in rural areas. 31% of those in rural areas report that they're dissatisfied with Mobile Broadband compared to 23% in urban areas. In the most rural areas 43% of households report trouble getting voice access in the home, compared to only 26% in urban areas.

Potential solutions

- The NBP will enable fast fixed broadband for almost all
- Changing handsets could lead to a significant improvement in in-building connectivity.
- Native Wi-Fi calling using the fixed broadband network will support in-home connectivity. Mobile operators offer Native Wi-Fi on some handsets.

Source: Frontier

8 CONCLUSIONS

Ireland is a digitally advanced economy and its connectivity needs will continue to grow. It therefore requires a range of connectivity infrastructures which supports its users' demand. Consumers' network agnostic devices will continue to roam across a number of different networks to take advantage of each network's specific capabilities and characteristics. In practice all our devices will use a patchwork of networks at different times of the day or for different purposes and no single network (mobile or fixed) will provide all the connectivity solutions required by users.

Ireland has networks which support connectivity needs. The combination of commercial plans by telecoms providers, and the implementation of the NBP is expected to result in all households in Ireland having access to fixed high speed broadband services in the coming years. The NBP is central not just to the delivery of fixed broadband to all households in Ireland but also in allowing users to maximise the connectivity experience (voice and data) from their mobile devices indoors. Ireland already has high population coverage of mobile services, including 4G mobile services. However, there are still consumers who have a poor connectivity experience for a variety of reasons, particularly in rural areas and measures are required to improve this experience while catering for the connectivity needs of the broader economy in the future.

Ireland faces challenges in providing connectivity

Ireland faces challenges in meeting the connectivity needs of consumers and businesses. The relatively high proportion of the population that live in rural areas, and the high density of road network per capita both present challenges to network operators. Other factors such as insulation used in modern building materials can also make indoor mobile connectivity difficult. The high costs of supplying mobile connectivity to rural areas will inevitably mean that the level of commercially provided connectivity in the most rural areas will be different to the connectivity in densely populated urban areas.

Public policy measures can be put in place to support rural coverage. The NBP is an obvious example of public intervention in fixed networks. However, given the costs associated with pushing geographic coverage beyond certain levels, extensive mobile interventions could be inefficient given the higher social values that could be generated from an alternative allocation of the resources that would be necessary to deliver this. As such any future obligations or interventions should be designed around Ireland's distinct characteristics and recognise the cost of achieving certain targets.

Connectivity should initially focus on coordinating existing resources

Consumers' current experience of connectivity can be impaired by inefficient use of existing resources. There are a number of actions which enable better use of existing networks or can alleviate constraints on investing in new network resources which can lead to improvements in connectivity experience required by society and over a relatively short time frame.

In particular certain actions to support improvements connectivity experience do not impose the same costs as blanket coverage obligations and can deliver certain improvements more quickly. For example individuals can select devices which support better signal performance, they can install repeaters, or use native Wi-Fi calling to makes calls over fixed networks, or they can use online tools to choose mobile networks which offer enhanced connectivity in certain areas. Further, the Mobile Broadband Taskforce is identifying immediate solutions to address deficits in mobile service and broadband coverage, such as actions to reduce costs of roll out (by changing planning regulations). ComReg also produces research and publishes information to assist consumers in making informed decisions. Jointly these actions can improve connectivity outcomes.

Future spectrum awards provide the opportunity to improve connectivity

ComReg is planning for further spectrum releases which will support further investment in mobile networks. It is considering bringing 700 MHz spectrum to the market which could also support investment in connectivity in rural areas and could support 5G services. In combination with higher frequency spectrum (such as; 2.1 GHz, 2.3 GHz and/or 2.6 GHz) it could also support capacity in more densely populated and congested urban areas. This award which will also more readily enable three-band Carrier Aggregation (a key technology that will reduce the cost of high-speed connectivity) could significantly boost speeds currently obtained by existing consumers.

Future coverage obligations need to be realistic

Coverage obligations on mobile network operators (i.e. spectrum licence conditions) can be effective in targeting coverage at specific areas where coverage is required within a specified timeframe. However, in making such public interventions policy makers need to balance costs and benefits (since costs are likely to fall on subscribers, and taxpayers). For example the FMC Report noted that it would cost €1,860m to provide 30 Mbps coverage to 99.5% of geography. Such costs are far in excess of the likely value of the radio spectrum and any future obligations should consider how best to promote coverage where it is needed most. This does not mean that coverage obligations have no place. In fact, coverage obligations should play an important role in maximising the level of coverage that can be provided by commercial operators, by protecting against failures of competition that lead to sub-optimal levels of coverage. However, the level of any obligation needs to be carefully selected.

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