# National Broadband Plan

# Conclusion of the Mapping Exercise for the Intervention Area Pre Deployment

# eir Response

## Introduction

The details outlined are the eircom LTD (trading as "eir") ("eir") response to the Consultation on the Mapping for the proposed Intervention Area. The eir response is based on Premises where the Minimum requirement of 30M is available today, and the associated premises documented on the Advanced Pre-Qual (APQ) file shared with Industry.

In total, today eir have High Speed Broadband available to over 1.9 Million Premises in Ireland through either our FTTH or FTTC fibre solutions.

In February 2019 eir announced a further deployment of FTTH within the Commercial Blue area to cover 1.4 million premises and do anticipate to pass approx. 52k of those Premises identified as "In Fills" within the Intervention Area.

We have learned from our experiences rolling out FTTH in rural Ireland that retaining flexibility over which areas are passed in what order is critical to a fast and efficient FTTH rollout. This allows eir to respond to challenges such as licence availability by shifting resources to other areas. eir has committed to an ambitious five-year programme for delivering FTTH to 1.4 million premises and are not in a position to sign a Commitment Agreement for a specific 52k which we understand would be required to remove these premises from the Intervention Area. Therefore these premises are not included within our submission and no commitment to the specific In Fill Premises will be provided.

## The Intervention Area.

Having reviewed the details of the consultation and the Premises indicated our response is 3-fold:

1) As part of our 300k Rollout under the Commitment Agreement, we have passed an additional 40k Premises, both within the Intervention Area and within the 300k Committed Polygon. Each of these specific Premises appears on the open eir Advanced PreQual file (APQ) and can order services greater than 30M today. The details of these Premises can be found in Appendix A.
2) We acknowledge the additional 45k potential Additional Premises identified by DCCAE within the Commercial Blue area where it was believed that the requirements under NBP were not being met. A detailed analysis of these was done and we have determined that 5,944 have potential service of greater than 30M from open eir today, provided through a mix of both FTTH and FTTC. Each of these Premises are on our APQ file and available for order. The list of the specific 5,944 and the service available can be found in Appendix B. Columns P and Q to the table to provide the Address Identifier (ARD ID) and associated Max High Speed, which links these premises to an entry in our APQ file.

In accordance with the consultation we acknowledge the assessment criteria to be followed:

- Technical Criteria
  - Appendix C provides a detailed brief on the Technical Solution we have deployed in our network to provide the services required.

  - This was previously submitted as part of our 300k Assessment, and through the deployment we have proven the solution. The document outlines the provision of both our FTTC and FTTH networks, the backhaul in place and ultimately the end to end solution providing the minimum of 30M to each Premise.
- Deployment Information
  - As this network is in situ and the service available to the premises today, this is not relevant to our submission.
- Financial Information
  - As this network is deployed, no finance is required.
- Signed Declaration

3) As part of our 300k Programme Close out we have identified a small number of Premises where we have hit roadblocks in our provision of fibre. There are two primary reasons: 1) Premises where the geolocation has changed through the GeoDirectory and the geolocation no longer corresponds to a premises adjacent to our rollout, 2) where a deployment issue has been met that we have not been able to overcome despite effort. As we are unable to give a firm deadline for connection to these premises at this stage, we believe it is the interests of the home owners to include these premises within the Intervention Area. The details of these premises are included in Appendix C

## The Challenges of Deploying Networks.

As part of the consultation, DCCAE are seeking information on the barriers to deploying NGA networks. Having successfully rolled out the largest rural fibre infrastructure programmes in Europe, eir has gained unique insight into the challenges of deployment. Many of these have been shared on an ongoing basis with DCCAE through the regular 300k reviews.

It is the installation of any required civils infrastructure that is the main obstacle when rolling out broadband and in particular the permissions necessary to carry out the work.

For Ireland, the local authorities have a standard process for licence applications. However, in our experience, different local authorities have different interpretations and implementations of the standard process, with a resulting wide variation in the turnaround times for licences.

The timing of projects can also be impacted by local authority road schemes and a natural requirement to dovetail works. It is not always possible to align the local authority schedule with the broadband roll-out schedule.

The licence process for N roads has an additional layer of applications. This process strangely applies only to telecommunication services and not to other utility services. TII are the licencing authority for telecommunications services on N roads but not for the other services. There is also a higher specification for roadworks on N roads.

Where new poles are required, there is deviation on how local authorities apply the guidelines, particularly in relation to the adoption of a 5m clearance from the carriageway edge. While the intention of the guideline is clear, the practical implication, particularly in the rural setting, can result in one of two scenarios:

- Locating the pole on private property where it can be difficult to get the private wayleave, and can lead to ongoing access issues.
- Having to use duct instead of poles. This is an expensive undertaking, with further costs if the works are subject to full carriageway reinstatement charges.

As we have progressed with our rollout we have also seen a challenge with the use of our existing Poles, or refusal of new poles for aesthetic reasons. Poles are seen as "Street Clutter" and we have had request to remove our existing pole infrastructure. This leads to delays in rollout and can drive additional cost into build costs.

## eir's future plans

As the Department are aware, and as we have made public, following on from our 300k Rural FTTH programme, we are launching an Urban Programme, "Ireland's Fibre Network" (IFN), bringing our FTTH technology solution to 1.4M homes across Ireland. This technology solution will be available to the consumer through our own eir Retail brand, or through other operators via open eir Wholesale.

The rollout for this programme has commenced, with the first Premises expected to be ready for order in January 2020. As part of our regulatory obligations to Comreg we will be advising Industry 6 months ahead of Premises being available of the areas targeted for release, with the specific Premises to be "Ready for Order" being added to our APQ file 28 days prior to that.

This is the next major programme for eir, and it builds on our successful 300k Rural Ireland programme.

# CONFIDENTIAL

# eir's Response to DCCAE's Mapping Consultation - Supplementary Information Request

## Confidentiality Statement

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## Contents

# 1 Executive Summary

This document is eircom Limited's ("eir") technical response to the request for information issued by the Department of Communications, Climate Action and the Environment (the "DCCAE") to finalise the Mapping exercise under the National Broadband Plan ("NBP")

In 2017, eir entered into a Commitment Agreement with DCCAE to provide High Speed Broadband to 300,575 Premises in Rural Ireland. As part of the assessment of eir's ability to deliver on the Commitment Agreement a detailed technical submission was provided that outlined the solutions provided within the eir network, in terms of it FTTC deployment and planned FTTH build. The Premises that eir have identified as part of this latest submission have high speed broadband available to them today utilising either the FTTC or FTTH network, meeting the minimum requirements under the NBP.

# 2 Technical Information

## 2.1 Introduction

***The Department is seeking information in relation to the network solution, to assist in verifying the service available to the identified Premises.***

## 2.2 Generic Information

***1. A description of the overall network architecture.***

The Premises included within our submission have High Speed Broadband available to them today either through our extension FTTC network, or our FTTH network predominantly rolled out as part of our 300k Commitment Agreement with DCCAE.
Both networks are well established and the quality of the network known and reported as part of our Comreg obligations.
All these programmes have been successful, and today more than 1.9 Million Premises have access to High Speed Broadband. The network architecture is shown in Figure 1 below.

eir's Next Generation Access (NGA) network is based on VDSL2 technology. The network architecture is also shown in Figure 1 below:

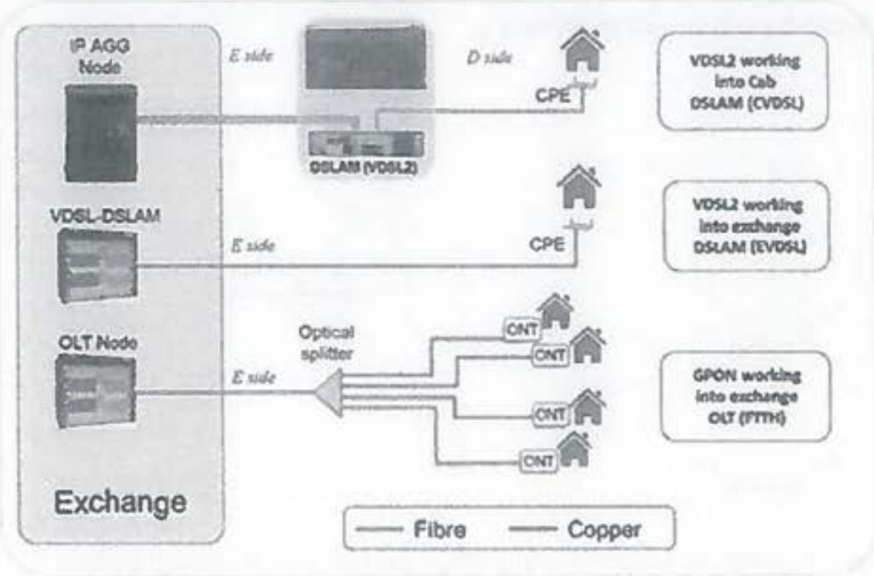



Figure 1: NGA Network Architecture

**CVDSL and EVDSL**

Cabinet launched VDSL (CVDSL) is used to serve customers from street-side cabinets, which allows us to reduce the length of the copper connection to the customer. In the case of customers who are connected to the exchange directly or who pass through very small cabinets, we will launch VDSL from the exchange (EVDSL).

An enhancement on VDSL2 was the implementation vectoring which reduces the crosstalk interference between different VDSL systems on the same cable binder. Vectoring technology predicts and cancels the interference to deliver higher speeds and can improve the maximum VDSL downstream speed from ~70Mb/s to ~100Mb/s. Because the vectoring processor must be aware of all interference sources on a cable, it is necessary to have only a single VDSL operator on a cable to maximise the benefits.

eir was one of the first operators in the world to launch vectoring for CVDSL.

The 17a MHz VDSL bandplan for VDSL is used throughout the associated network.

The speeds that can be achieved by VDSL are distance dependent. Figure 2 below shows VDSL speeds vs distance in both the vectored and non-vectored cases for 0.5mm cable.

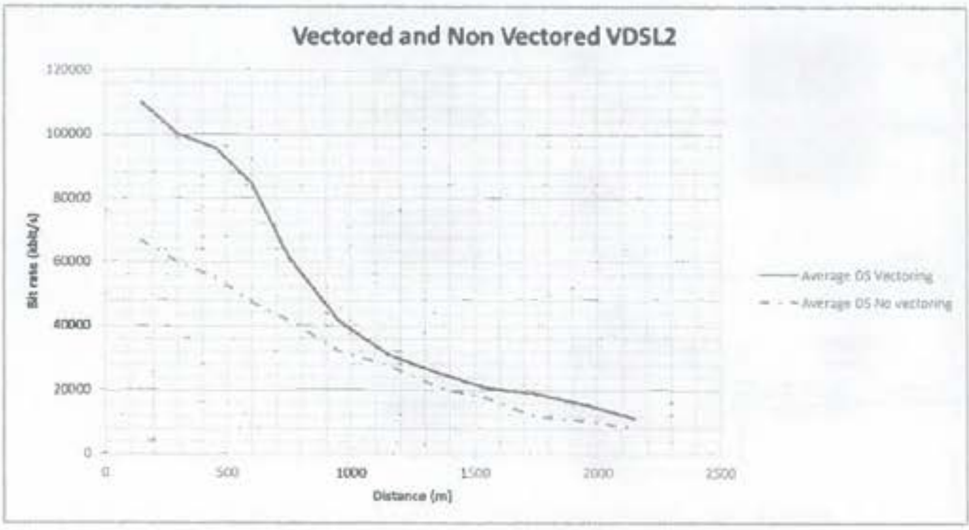



Figure 2: Bit rate (Kbps) versus line length (m) for VDSL (vectored and non-vectored)

### *FTTH*

Today, over 375k Premises have access to our FTTH technology, providing a very high speed service up to 1Gb/s.

The network architecture is set out in Figure 1.

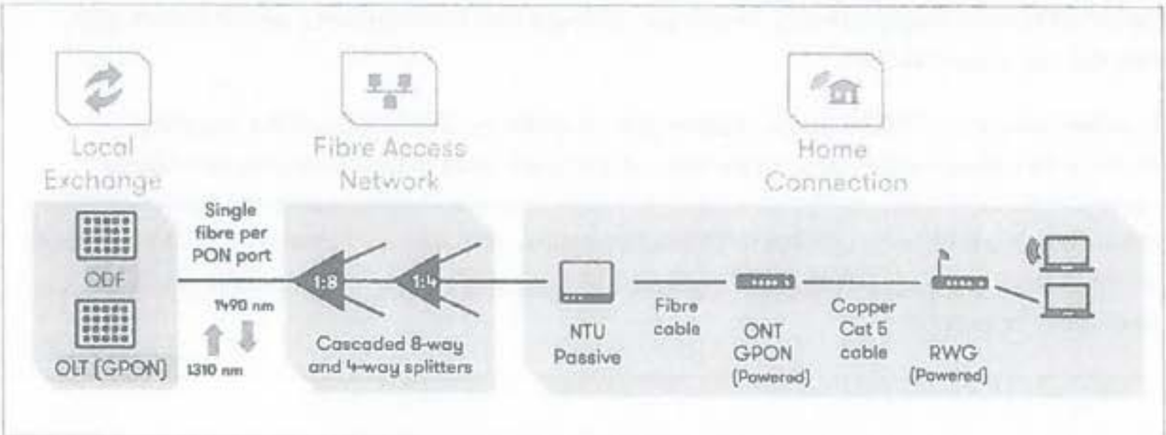



*Figure 1* *Overview of ODN design*

The configuration is a two stage 32-way split using an 8-way primary splitter followed by a 4-way secondary splitter. The 4-way secondary splitter is coincident with the Customer Fibre DP. The deployed OLTs are 2.5G GPON.

The chosen optics (C+), splicing configuration, allowance for a co-existence element (CE) gives a reach of 16km. This range exceeds the length of the ribbons in scope. The CE allowance caters for the future deployment of fibre unbundling equipment as equipment becomes available and as this service is requested.

The design created supports 100% penetration with capacity for additional demand.

Figure 2 details how the fibre count is utilised.

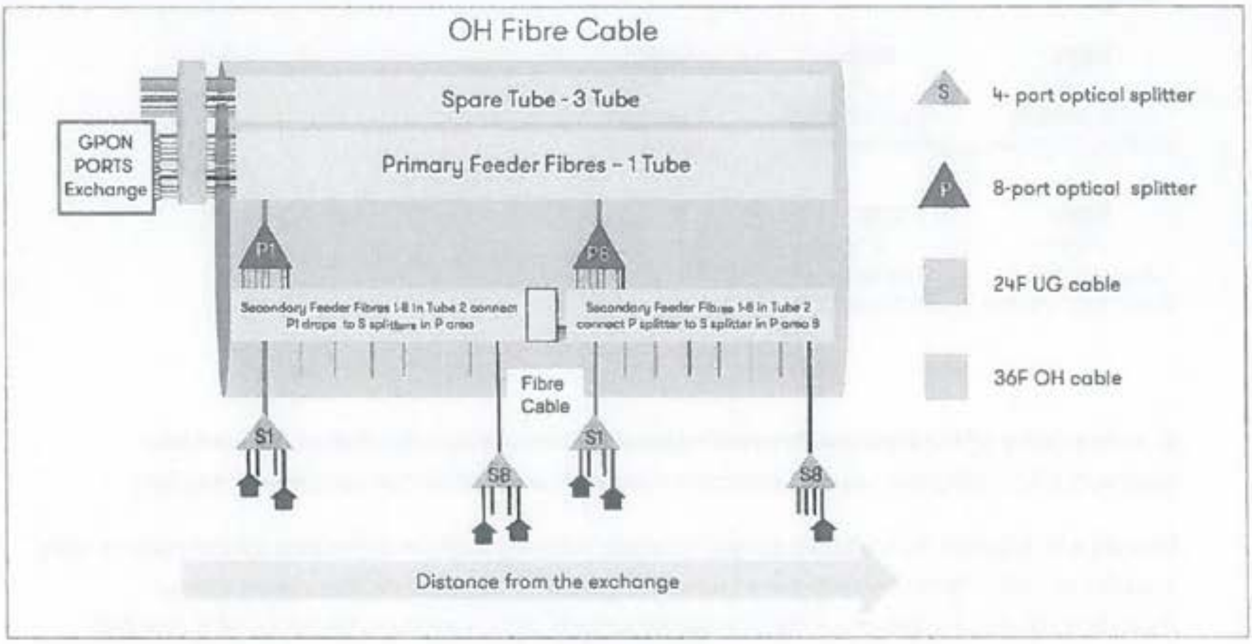



*Figure 2: Fibre network design*

A 36-fibre cable is deployed on the main arteries of a ribbon;-

- 12 of the 36 fibres in the main cable are used to feed up to 12 primary splitters.
- 8 fibres in the main cable are used for distributing the primary splitter outputs to secondary splitters located at FDPs.
- All remaining fibres are unallocated.

12-fibre cables are utilised on spur routes off the main 36F route; up to 8 of the 12 fibres on the spur are used to feed secondary splitters, the remainder are unallocated

***2. A description of the access network technology and the specification of the access equipment (including the relevant telecoms standards with which the equipment complies).***

The equipment used for each access technology is listed in Table 1 below:

| Access Technology | Equipment Used | Comment |
|---|---|---|
| **CVDSL** | Huawei MA5616 | |
| **EVDSL** | Huawei MA5600<br>Huawei MA5616 | Choice depends on number of lines that qualify for EVDSL. |
| **FTTH - GPON** | Huawei MA5600<br>Huawei MA5800 | MA5600 was deployed initially but switched exclusively to using the new MA5800 model which will support NGPON2 at the end of 2015. |

Table 1: Equipment used per access technology

Standards compliance documents and brochures/specifications for this equipment are attached below:

Huawei MA5800 V100R015C00 Produc

Huawei MA5600T Standard compliance.

MA5600T brochure.pdf

Huawei MA5616 Standards Complianc

MA5616 brochure.pdf

***3. A description of the backhaul network technology and the specification of the backhaul equipment (including the relevant telecoms standards with which the equipment complies).***

Eir uses a distributed, MPLS-based packet transport network with an underlying optical layer to carry broadband traffic from the customer to Internet handoff locations. Traffic is aggregated at Broadband Network Gateways (BNGs) in approximately 200 locations nationally, and forwarded to/from the Internet using a hierarchical MPLS/IP network. This relatively wide distribution of BNGs spreads the load around the network and reduces the impact of the loss of any one BNG site.

The BNG/Aggregation nodes are Alcatel-Lucent 7750 SR routers, which connect back to PE nodes over CWDM and DWDM optical transmission systems. The central IP/MPLS core consists of eight Alcatel-Lucent 7950 XRS-20 routers in four locations in Dublin. Connections to upstream networks on the Internet are made through four Border routers, Alcatel-Lucent SR-12e devices. The border router locations are Dublin, London, Frankfurt, and Amsterdam.

The metro/edge network links sites beyond the BNG locations noted above are known as APT sites. These typically use Alcatel-Lucent 7210 SAS-M carrier Ethernet (MPLS) devices, connecting back to their serving BNG node using dark fibre or passive CWDM. Although MPLS is used at this level of the network, no overbooking is carried out. There are approximately 500 remote APT sites in the network.

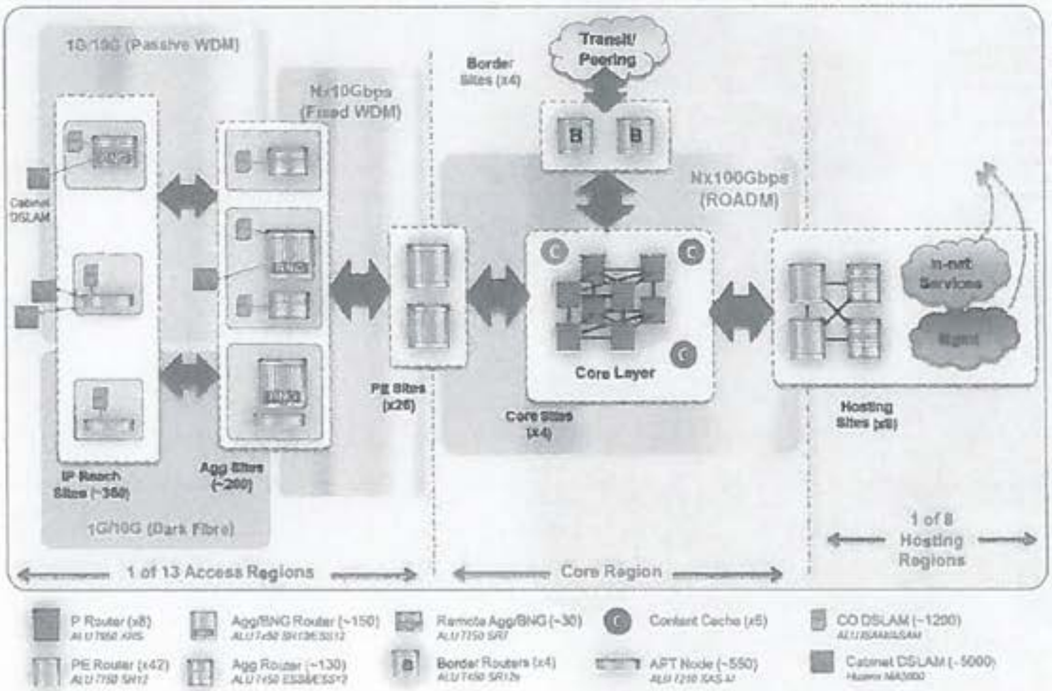



Figure 4: NGN Architecture

The national optical transport layer is composed of Nokia ROADM and OTN equipment at 29 locations which supports 88 channels per fibre at 100Gb/s or 200Gb/s per channel (depending on distance). Beyond the 29 main sites, reach is extended using Adva FSP 3000 DWDM and CWDM systems, passive CWDM, and direct fibre

| *Network Layer* | *Technology* | *Capacity per system* | *Comments* |
|---|---|---|---|
| Core – Core | DWDM | 1.7Tb/s | Delivered on ROADM |
| PE – Core | DWDM | 1.7Tb/s | Delivered on ROADM |
| Agg – PE | CWDM or DWDM | 80Gb/s or 320Gb/s | Delivered on Adva FSP 3000 |
| Metro | CWDM or direct fibre | 80Gb/s | CWDM, passive CWDM, or direct fibre used as appropriate |


Figure 5: Current optical transmission network

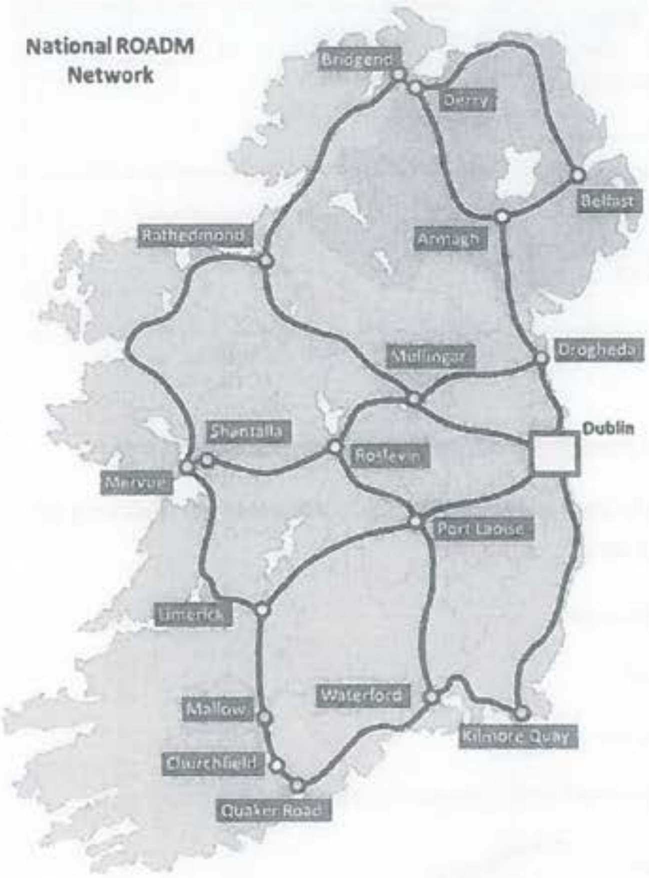



Figure 6: Upper-layer DWDM network

All nodes are centrally managed from eir's Network Management Centre in Citywest.

For information on supported technical standards, please see the following links:

| Platform | Purpose | Datasheet |
|---|---|---|
| 7750 SR | BNG, PE, Core | MKT2015019674EN_ 7750_SR_Portfolio_R |
| 7950 XRS | Core (from Q4 2015) | PR1502009169EN_7 950_XRS_R13_Datas |
| 7210 SAS-M | Rural edge network | MKT2015019672EN_ 7210_SAS_R7_DataS |

| | | |
|---|---|---|
| FSP3000 | Optical transmission | FSP_3000.pdf |
| 1830 PSS | Optical transmission (from Q3 2015) | MKT2014056021EN_ 1830_PSS_64_36_R7 |

Table 2: Documentation for supported standards for core nodes

***4. A design for the national backhaul network including any traffic and capacity assumptions.***

The national backhaul network is eir's existing NGN as described above. This network is reviewed on an ongoing basis using a number of inputs, including:

1. Current backhaul capacity, on a per-site basis
2. Historical traffic levels and growth rates
3. Forecast average per-user traffic at the busy hour

The design is based on the NGN architecture outlined in the answer to question (3) above.

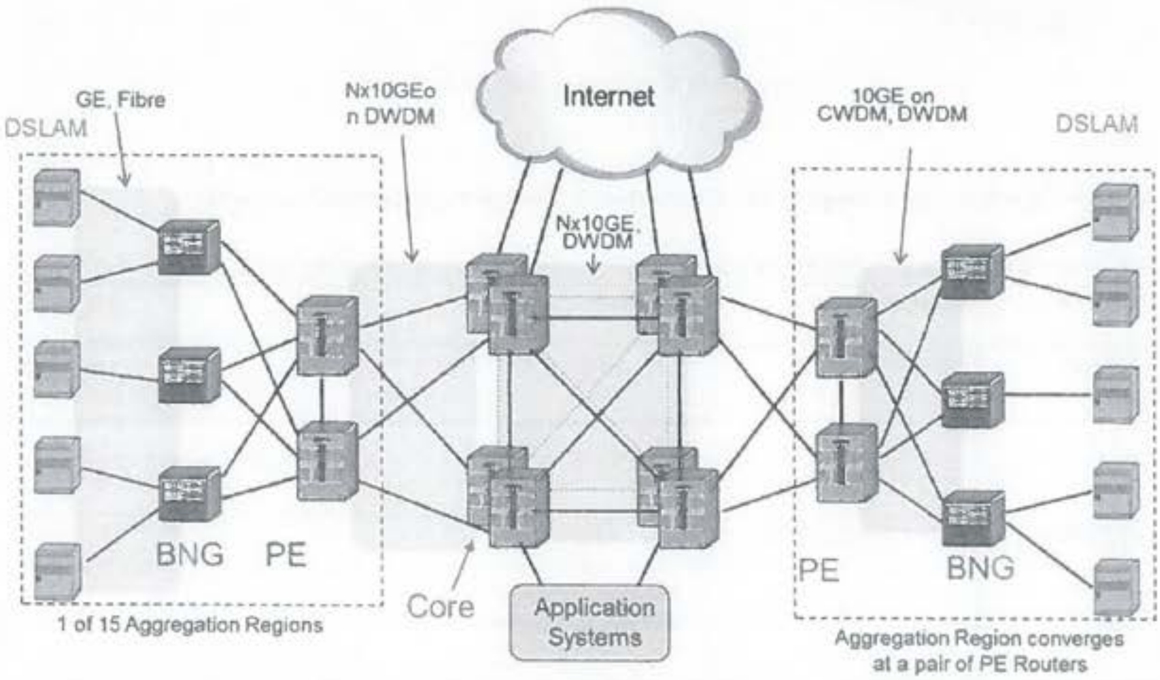



Figure 7: National Backhaul

Dimensioning of individual links is based on the per-user traffic forecasts. A 50% utilisation rule is applied at the BNG, PE, and Core layers to ensure that if one link goes down, the remaining link can carry the traffic. Once traffic exceeds 50% of the total installed link capacity at a site, the addition of a further backhaul link is triggered.

***5. The specification of all types of customer premises equipment which the operator plans to use.***

The CPE being deployed is the Huawei F2000 modem. The user guide and product description is embedded below.

| Device | Specifications |
|---|---|
| Huawei F2000 modem | eircom_F2000.pdf |

Table 4: CPE devices currently used by eir

***6. Coverage Data.***

All the Premises provided as part of this submission are on the latest version of APQ file as "Ready for Order"

The Advanced PreQual File is provided to service providers and details the services available (FTTH or FTTC) to all the addresses of lines (residential and business) that are served from a technically ready NGA cabinet and as such available for connection.

The file is updated weekly and is the definitive list of homes available for NGA services.

| | |
|---|---|
| **1)** ARD_ID: | Address Reference |
| **2)** FIBRE_TYPE: | FTTC or FTTH |
| **3)** RFO_DATE: | Date Cabinet Ready to Take Orders |
| **4)** NGA_EXCHANGE: | Name of Exchange Site serving the cabinet for NGA broadband services. |
| **5)** COPPER_EXCHANGE: | Name of Exchange Site serving the cabinet for Copper services. |
| **6)** CABINET_NUMBER: | Cabinet Number In Exchange Area |
| **7)** MAX_HIGH_SPEED: | Max High Speed Profile |
| **8)** MAX_HIGH_STABILITY: | Max High Stability Profile |
| **9)** UNIT_NO: | Used for Unit Number in Industrial Estate/Apartment Blocks |
| **10)** UNIT_NAME: | Used for Unit Name in Industrial Estate/Apartment Blocks |
| **11)** BUILDING_NO: | Used for Building Number in Housing Estates/Streets |
| **12)** BUILDING_NAME: | Used for Building Name in Housing Estates/Streets |
| **13)** LOCATION: | Postal Address Details |
| **14)** POSTAL_DISTRICT: | Postal District e.g. Dublin 16. |
| **15)** POSTAL_CODE: | (Blank – For Future Use) |
| **16)** COUNTY: | County |
| **17)** X_REF: | X Co-ordinate of Address (Blank – For Future Use) |
| **18)** Y_REF: | Y Co-ordinate of Address (Blank – For Future Use) |

Note 1: **RFO Date** indicates the date from which orders can be placed for that line.
Note 2: **MAX High Speed** indicates the maximum available profile for a rate adaptive high speed internet (HSI) profile. Similarly **MAX High Stability** will indicate the maximum available stable or non rate-adaptive (NRA) profile.

## 2.3 Platform Specific Information

### 2.3.1 Wired platforms

***1. Please provide the following data in a spreadsheet on a per access node basis:***

The embedded Excel file is the eir NGA Rollout plan as published to industry. This contains the VDSL and GPON nodes live per the September 2019.

***2. Please provide details of the CPE and the general locations where it is proposed to install it in the premises.***

Please refer to Section 2 question 5 for details of CPE. In general the location of the CPE equipment is within 30m of the network termination point.

***3. Please describe any planned use of technological advancements to increase broadband speeds (e.g. pair-bonding, vectoring, phantom mode, channel bonding etc.).***

We have not used pair bonding, phantom mode or channel bonding.

***4. Please describe the following inputs to the coverage map:***

***a. propagation model i.e. speed performance versus line length***

The NGA coverage map is based on VDSL coverage predictions. As outlined above, both cabinet launched and exchange launched VDSL are considered i.e. CVDSL and EVDSL. The coverage map is based on the use of vectoring for CVDSL cabinets and for EVDSL in the smaller 560 of the 860 NGA exchanges.

The graphs of bit-rate versus distance for vectored VDSL and non-vectored VDSL are shown in Figure 2 above. Based on these curves, the path lengths for vectored and non-vectored VDSL at 30Mbs are 1.2km and 1.1km respectively.

***b. supporting evidence including manufacturer's performance data and trial results***

The VDSL speed versus distance curves have been established based on years of lab and field work with xDSL technologies. Test cables, line simulators and network equipment have been used to model performance in the lab using realistic noise models. Field results and line test data have been used to augment the lab test results. These tests are used as the basis for eir's prequalification of customers requesting VDSL based service.

The VDSL curves shown above in Figure 2 were derived from tests in eir's reference network facility located in the Citywest Business Park in Dublin. A 20 pair (0.5mm) cable was fully loaded with VDSL2 in the test configuration depicted in Figure 8 below. The cable length was configured for lengths up to 1550m. Additional line length was added using a Sparnex LSX 2030 line simulator. The curves in Figure 2 are based on the average results for the different lines tested.

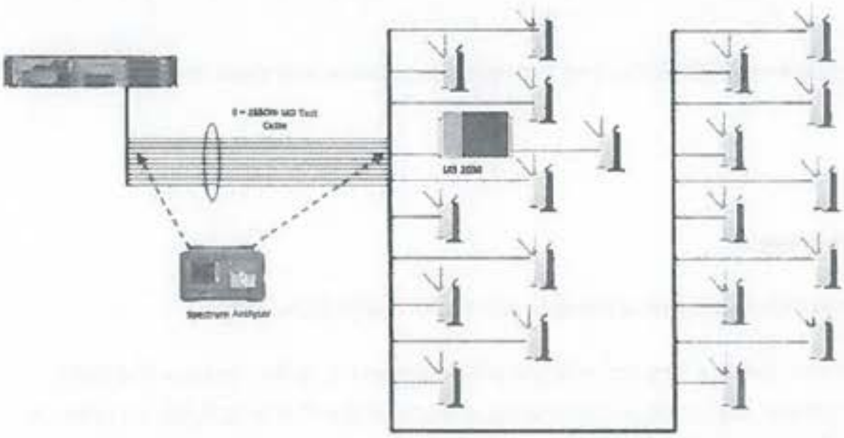


Figure 8 Test configuration for VDSL bit rate versus distance

These results have been confirmed by the speeds achieved in the field.

### *c. any assumptions made in translating straight line to actual route*

The distance between a customer location and its serving cabinet or exchange can be measured along the path travelled or as a radial distance. This relationship is illustrated in Figure 9 below. When plotting EVDSL or CVDSL coverage, it is easier to map coverage using radial distance and to use a conversion factor to convert path distance to radial distance.

Statistical analysis of radial distances and path distances shows that the relationship between path and radial distance is 1.6 to 1 in urban exchange areas and 1.2 to 1 in rural exchange areas.

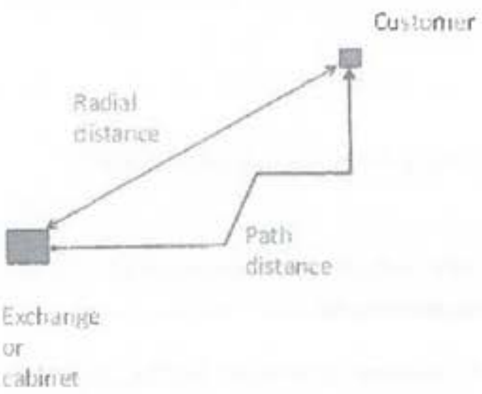



Figure 9: Illustration of path distance versus radial distance

*d. planning tool and associated configuration*

N/A – The Premises submitted have High Speed Broadband available to today.

***5. Please provide a full Excel-based link budget for the downlink and uplink including all intermediary step calculations i.e. include all formula used to calculate all line items (e.g. line A + line B + line C = line D). The link budget should include at a minimum the following line items and their associated units:***

We assume this question relates to FTTH GPON and the responses below are therefore in relation to GPON.

**Transmit and Receive Power Levels**

Both devices have optical line interfaces that adhere to the ITU-T G.984 standards.

The GPON OLT can support both B+ or C+ optics and the ONT supports only B+ optics while both support Forward Error Correction (FEC). We are providing power budgets for both types of optics as both may be used in our GPON implementation.

The loss that can be tolerated on the GPON ODN is determined by the optical transmit and receive power levels which are shown for B+ and C+ optics in Table 6 below based on ITU-T G.984 standards.

| | B+ Optics | C+ Optics |
|---|---|---|
| Minimum Launch Power (dBm) | +0.5 | +3 |
| Minimum Receive Power (dBm) | -28 | - |
| Minimum Receive Power w/ FEC (dBm) | -30 | -32 |
| Maximum Loss (dB) | 28.5 | 35 |

Table 6: GPON Power Levels

**Power Budget with B+ optics**

The power loss budget with B+ optics is 28.5dB as shown in Table 3 above.

**Power Budget with C+ optics**

In the case of C+ optics, ONTs continue to use B+ optics, but the superior performance of the C+ optics on the OLT gives a higher loss budget.

In the downstream direction we have C+ transmit power (3dBm) with B+ receiver sensitivity, enhanced with FEC (-30dBm) giving a downstream power budget of 33dB.

In the upstream we have B+ transmit power (0.5dBm) with C+ receiver sensitivity (-32dBm) giving an upstream power budget of 32.5dB.

As the link budget is upstream limited this dictates a power loss budget for the ODN of 32.5dB.

This is summarised in in Table 7 below:

| | Downstream | | Upstream | |
|---|---|---|---|---|
| | Power | Optics | Power | Optics |
| **Minimum Launch Power (dBm)** | +3 | C+ | +0.5 | B+ |
| **Minimum Receive Power (dBm)** | -30 | B+ FEC | -32 | C+ FEC |
| **Power Budget (dB)** | 33 | - | 32.5 | - |

Table 7: Power Loss Budget C+ Optics

**Optical fibre cable losses**

The GPON fibre cable will comply with ITU-T G652.D. Using existing GPON (ITU-T G.984) and future XGPON1/NGPON2 (ITU-T G.987/G.989) technologies working between 1260-1625nm an optical loss of 0.4dB/km will provide a small safety margin.

In urban areas fibre cable will be spliced approximately every 800m which equates to a loss of 0.125dB per km (0.1dB*(1km/0.8)=0.125dB/km).

**Splicing and connector losses**

All fibre cable in the GPON ODN will be fusion spliced from the OLT to the fibre distribution point (DP). For the link budget calculation we will assume that fusion splices have a loss of 0.1dB to allow for a safety margin, although a best practice fusion splice will have an attenuation of less than this.

Manual or mechanical splicing may take place at the home installation stage but will be kept to minimum to reduce optical losses; the best practice loss for this type of splice is 0.1dB.

In the GPON ODN optical connectors are used at Optical Distribution Frames (ODFs) and at active equipment ports. The insertion loss is the optical power lost through a mated connector pair. We will use angle-polished-connectors (SC-APCs or LC-APCs) which have an insertion loss up to 0.35dB

**Optical splitter losses**

Optical splitters in a PON network are passive devices and come in a variety of split ratios mostly in a factor of $2^n$ (1:2, 1:4, 1:8, 1:16 and 1:32). All optical splitters are basically built from units of 1:2 splitters in cascade. An optical splitter essentially divides the input power across the outputs with some inefficiencies. Optical splitters have the biggest impact on the optical link budgets and too large a split ratio limits the fibre distance.

The 1:8 primary stage splitter has a loss of 10.38dB

The 1:4 second stage splitter has a loss of 7.25dB.

The total optical splitter loss across both primary and secondary splitter is 17.6dB.

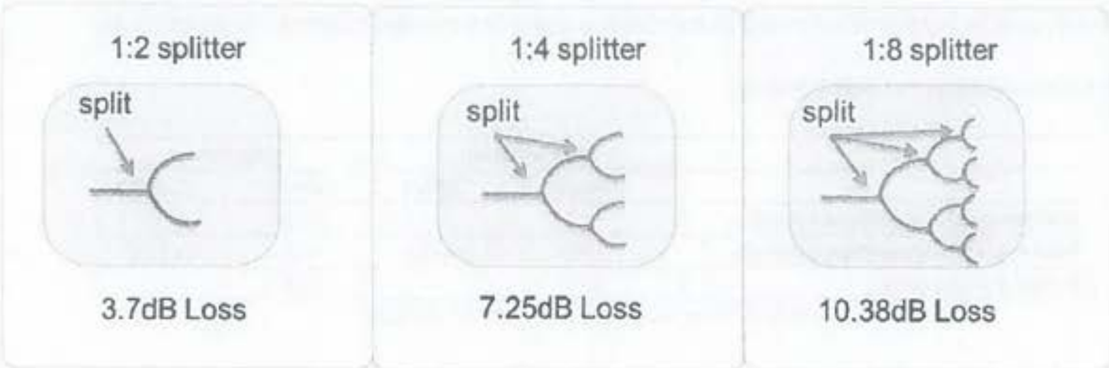



Figure 2 Illustration of splitter makeup and optical loss

**Co-existence Element**

GPON, XGPON and NG-PON2 all operate at different wavelengths so they can co-exist on the same ODN. A co-existence element is required to 'mix' the different wavelengths on to the ODN so it is prudent to include this in the power budget calculation from the start. A loss of 1.3dB is associated with this co-existence element. When two connectors are included with a loss of 0.35dB each, the total loss for the co-existence unit is 2dB.

***Loss Budget Calculation***

The points of signal loss on the GPON ODN with are illustrated in Figure 3.

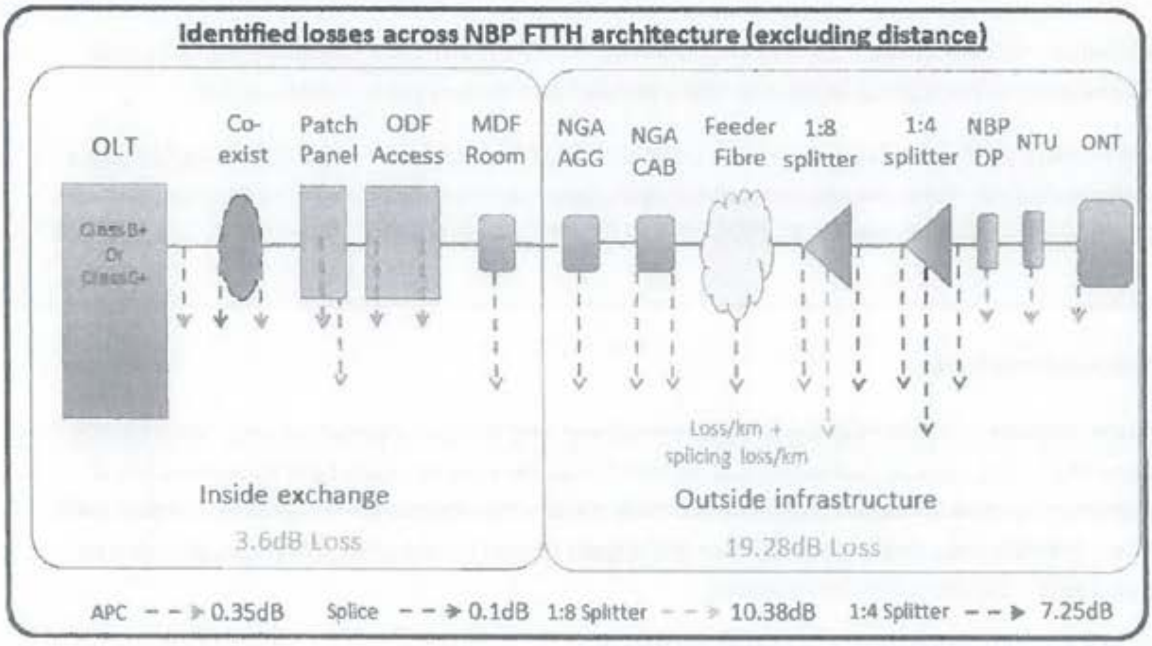



Figure 3 GPON ODN and points of signal loss

The assumptions about component losses outlined in the preceding paragraphs are summarised in Table 4.

| Optical data sheet - reference | | |
|---|---|---|
| **Items** | **Source** | **Loss (dB)** |
| Optical connectors | ADC Telecoms | 0.35 |
| Fusion splice loss | ADC Telecoms | 0.1 |
| 1x8 splitters | ADC Telecoms | 10.38 |
| 1x4 splitters | ADC Telecoms | 7.25 |
| Fibre loss/km @ 1310nm | ITU-T G.652D | 0.4 |
| Fibre loss/km @ 1550nm | ITU-T G.652D | 0.3 |
| Co-existence element | ALU | 1.3 |
| | | |
| **Fibre and fibre splicing loss per km** | | |
| Splice Separation (km) | | 0.5 |
| Number Splices per km | | 2 |
| Splice Loss per km (dB) | | 0.2 |
| Fibre Loss per km (dB) | | 0.4 |
| ***Total Fibre Related losses per km (dB)*** | | 0.6 |

Table 4 GPON component loss assumptions

The total fixed losses on the ODN excluding fibre are shown in Table 5.

| Inside Exchange | Unit Loss (dB) | Qty | Total Loss (dB) |
|---|---|---|---|
| APC connectors | 0.35 | 6 | 2.1 |
| Fusion splices | 0.1 | 2 | 0.2 |
| Co-existence element | 1.3 | 1 | 1.3 |
| | | | 3.6 |
| | | | |
| **Outside infrastructure** | **Unit Loss (dB)** | **Qty** | **Total Loss (dB)** |
| APC connectors | 0.35 | 3 | 1.05 |
| Fusion splices | 0.1 | 6 | 0.6 |

| | | | |
|---|---|---|---|
| 1:8 splitter | 10.38 | 1 | 10.38 |
| 1:4 splitter | 7.25 | 1 | 7.25 |
| | | | 19.28 |
| | | | |
| **Total Fixed Losses (dB)** | | | 22.7 |

Table 5 GPON Fixed Losses

The headroom for fibre related losses in the case of B+ and C+ optics is shown in Table 6.

| | Loss Budget (dB) | Fixed losses (dB) | Headroom (dB) |
|---|---|---|---|
| B+ optics | 28.5 | 22.88 | 5.62 |
| C+ optics | 32.5 | 22.88 | 9.62 |

Table 6 GPON remaining power budget after fixed losses

The fibre distances that can be achieved with our ODN architecture for both B+ and C+ optics are shown in Table 7.

| **NGA optical reach after fixed losses** | | | |
|---|---|---|---|
| | **Headroom (dB)** | **Fibre & fibre splicing loss per km** | **Optical reach (km)** |
| B+ optics | 5.62 | 0.6 | **9.4** |
| C+ optics | 9.62 | 0.6 | **16.0** |

Table 7 GPON achieveable fibre reach

In summary, using C+ optics a reach of 16km can be achieved allowing for a co-existence element. eir is deploying C+ optics.

***6. Please describe the planned approach to interference management in the access network making reference to frequency plans and any issues associated with the transmission medium.***

eir adheres to the Copper Loop Frequency Management Plan version 7.

***7. Regarding any existing equipment or plant which the planned network will reuse (including copper wires, coaxial cable, poles, optical fibre), please describe:***

***a. the general state of the existing equipment or plan***

eir's network utilises VDSL technology (CVDSL & EVDSL) and FTTH.

As of September 2019 eir has passed in excess of 1.9 Million homes with infrastructure providing 30Mbps or above and our existing assets have been successfully utilised to deliver this, along with the provision of new infrastructure particularly within our 300k Rural Programme.

***b. the impact of the existing equipment or plant on the quality of service***

N/A This is existing network.

***c. the approach to mitigating the risk of equipment or plant not meeting sufficient quality standards to meet the planned quality.***

N/A This is existing network.

### 2.3.2 Wireless Platforms

***Each operator whose planned network will use a wireless access technology, including wireless deployments where the CPE is installed in a fixed configuration, i.e.; fixed wireless access, is requested to provide the following information for their network rollout: (please write "not applicable should this not apply to your technology platform.)***

Eir Mobile has an extensive 2G, 3G and 4G network where both 3G and 4G would be considered high-speed mobile networks. However in the context of NGA eir has not used the coverage from these networks for the mapping and will therefore not be providing detailed response for this section.

Contents

**Preliminary**

We regret that due to the very short space of time allowed by the Department for this Consultation and due to the very large and time consuming amount of data required to fully comply with its requirements we have been unable to address the totality required. We and other SME FWA ISPs have written to the Department in September explaining the problems that this short time-scale holiday-centred consultation has caused and seeking an extension of time. It is most regrettable that to-date none has been forthcoming.

# A1 Technical Information

## 1 Introduction

We have built our network around having good bandwidth with consistent and low latency, so as to support all converged IP services. We support many businesses and homes with Voice over IP VoIP telephony services. In fact our clients have a wider choice of telephony offerings with Voice over IP which helps our customers access other services and reduce cost All of which is great our customers.

The advances in wireless broadband technology in the past 15 years has been very considerable and particularly significant in the last 4-5 years. In that time, by our company keeping up with the latest in wireless technology we have been able to deliver the benefits of reliable high speed broadband to Rural Ireland and, as a result, there is a wide variety of converged services available to our customers. In fact, more than half of our customer internet traffic is now video based, such as streaming video content from:

- RTE
- BBC iPlayer
- Apple TV
- YouTube
- Netflix
- High Resolution CCTV for our customers peace of mind and security and indeed farmers for monitoring their animals' welfare

In addition to this we support many businesses / homes with Voice over IP VoIP telephony services.

A number of our regional ISP colleagues have deployed their own IPTV distribution platforms for their ISP Customers, these operators include:

- Airwire Ltd.
- Real Broadband Ltd.
- Kerry Broadband Ltd.

They are very pleased with the results and we are actively considering collaborating with them and other operators to bring IPTV over our own high quality high speed broadband network.

We also support business users with remote working solutions through VPNs, Remote Desktop Environment and cloud-based productivity suites. Our customers report excellent results with video conferencing which allows for more remote working less commuting, less traffic congestion, reduced carbon footprint and a greater quality of life for our customers in Rural Ireland. We are delighted that our customers reap the benefits of high speed broadband in Rural Ireland today, benefits, we might add that exist at no cost to the taxpayer.

## 1.1Description of network Architecture

Currently we have two independent connections into INEX – total capacity of 20Gbps and two other transit providers on a 10Gbps ports. Total capacity of our transit providers – 40Gbps

This capacity is spread out using multiple fiber connections into different parts of our network. Currently we are using 4 fiber providers: enet, virgin media, eir, euNetworks

Rest of the network is built using wireless links using 17GHz and 24GHz radio links. Network was build with few alternative routes to fiber PoP.

IPv6 was introduced into our network two years ago as dual stack configuration.

## 1.2. Access network technology

We operate a Fixed Wireless Access (FWA) Network in the ISM 5GHz & License Exempt 5.8GHz bands. We use Ethernet based data link layer technology. For our NGA Access Deployment we have chosen RADWIN JET integrated Base Station/Sectors and Subscriber Units.

On our Base Station sites, we have deployed Sectors with the technical specifications as outlined in the following section. They have already been deployed following the deployment strategy which allows for self-funded organic growth and infill as the site matures and consumers become aware of the improved new service offering available to them.

On a given site that has 360 Degrees field of view (on top of a hill / mountain) we have deployed 4x 90-degree RADWIN JET sector antennas to provide coverage in the area. On a Base station site that has less of a field of view, In that case we have deployed the requisite number of 90-degree RADWIN JET sector antennas to cover that area.

RDWIN JET delivers the highest possible capacity per given distance. It supports broadband connectivity of up to 3Gbps per 4-sector site and enables 'triple-play' services with HD/4K quality. The RADWIN JET sector antenna's high gain, achieved with beamforming technology, combined with its wide channel bandwidth support and constant transmit power in all modulations, increases the actual end-user capacity for a given distance while maximizing the distance per given capacity.

Additional capacity is added on an ongoing basis to maintain performance in line with User expectations to ensure NGA Performance peak times.

### 1.2.1 Access network technology and the Specification of the access equipment

We operate in the ISM 5GHz & License Exempt 5.8GHz bands. We use Ethernet based data link layer technology. For our NGA Access Deployment we have chosen RADWIN JET sectors and subscriber units. The RADWIN JET sectors are powered using Power over Ethernet switches from RADWIN & MikroTik. MikroTik routers are used to forward customer Internet traffic over a Layer 2 / 3 redundant network.

A schedule of Routers used at each base station would be one or more of the following (depending on the site size:

- MikroTik RB1036 Range
- Mikrotik RB1100AHx4 Router with a capacity for Routing up to 4Gb/s
  - https://i.mt.lv/cdn/rb_files/RB1100Dx4-171013102032.pdf
- Mikrotik Cloud Core CCR1016-12G Router
  - https://i.mt.lv/cdn/rb_files/ccr1016-12G-190612120511.pdf
- Mikrotik Cloud Core CCR1016-12G Router for routing up to 4Gb/s
  - https://i.mt.lv/cdn/rb_files/ccr1016-12G-190612120511.pdf
- Mikrotik RB4011iGS Router for capacity for routing up to 4Gb/s
  - https://i.mt.lv/cdn/rb_files/RB4011-RM-180919132428.pdf

A Schedule of PoE Switches on base stations are outlined below.

- CRS328-24P-4S+RM
  - https://i.mt.lv/cdn/rb_files/CR328-24P-4SplusRM-180424120301.pdf

### 1.2.1 Base Station / Sector Technology Deployed

The RADWIN JET beamforming offers service providers a unique set of benefits; high service performance that is applicable to a wider range of customer segments, and low TCO (total cost of ownership). RADWIN JET beamforming delivers reliable connectivity in the licence-exempt 5GHz band.

RADWIN JET PtMP beamforming antennae have a very narrow beam width (8°) which imitates PtP transmission to end-users. Combined with RADWIN's air-interface capabilities (i.e. fast-ARQ, unique adaptive code-modulation, adaptive MIMO-diversity and dynamic channel bandwidth per end-user) RADWIN JET is second-to-none in radio interference mitigation, which ensures reliable connectivity in tough congested spectrums.

RDWIN JET delivers the highest possible capacity per given distance. It supports broadband connectivity of up to 3Gbps per 4-sector site and enables 'triple-play' services with HD/4K quality. The RADWIN JET sector antenna's high gain, achieved with beamforming technology, combined with its wide channel bandwidth support and constant transmit power in all modulations, increases the actual end-user capacity for a given distance while maximizing the distance per given capacity.

JET Beamforming enables service providers to deliver greater network capacity with less spectrum and less wireless infrastructure. RADWIN JET's ability to use only two (2) frequency channels per network, combined with high spectrum efficiency, enables it to deliver the highest capacity per available clear spectrum in unlicensed bands. A built-in GPS receiver assures TDD synchronization between all sites, minimizing self-interference and maximizing spectrum utilisation. Its superiority in spectrum efficiency and the extra distance it supports, reduces the number of towers, base stations and backhaul required per network

RADWIN JET's dynamic bandwidth allocation (DBA) ensures a Committed Information Rate (CIR) for heavy bandwidth applications, business customers and IPTV service. JET's dynamic bandwidth management allows residential oversubscription, while maintaining overall high sector capacity without capacity reduction. RADWIN DBA guarantees that not only will the throughput not be degraded when more subscriber units are integrated into the system, but on the contrary – performance (throughput and latency) can be improved when such scenarios occur.

The DBA algorithm is responsible for allocating the radio frames to the remote radios. The purpose of this allocation is to ensure the quality of service to each of the remote unit in terms of delay and throughput and in parallel provide the maximum possible peak rate.

The pre-allocated bandwidth defines the assured capacity and delay for each radio. The DBA is responsible for assigning additional bandwidth to a radio by either using the unallocated bandwidth or re-assign "unused" downlink bandwidth between different radios.

When more subscriber units are integrated into the system, they can be defined as "Best-Effort" users, or to be assigned with "committed" resources (percentage of the sector capacity) in order to guaranty SLA under congestion. When DBA comes into action, minimum service is maintained while peak rates are granted when conditions apply.

Under no circumstances or conditions, will there be service degradation due to newly added subscribers into the sector.

At the core of the RADWIN JET is a proprietary air interface protocol that enables carrier-class wireless Ethernet services in licence-exempt bands. To ensure high quality and reliable delivery of these services, RADWIN radio systems employ several mechanisms that work together to mitigate interference:

- Automatic Adaptive Rate
- Forward Error Correction (FEC)
- Advanced Automatic Repeat Request (ARQ) Mechanism
- Non-interrupted transmission
- Orthogonal Frequency Division Multiplexing (OFDM)
- Automatic Channel Selection (ACS)
- Network Synchronisation (GPS) (TDD sync)
- Dynamic Channel Bandwidth Allocation (D-CBA)
- Smart BEAMFORMING & BEAMSTEERING (2nd Gen)

- RADWIN Jet Air 250Mbps Integrated Base Station / Beamforming Sector with built-in GPS sync
  - PDF Datasheet attached "RW-5AB5-2654.pdf"
- RADWIN Jet Pro 750Mbps Integrated Base Station / Beamforming Sector with built-in GPS sync
  - PDF Datasheet attached "RW-5BG5-2650.pdf"
- RADWIN Jet PtMP Brochure
  - PDF Datasheet attached "RADWIN JET PtMP Brochure"
- Explainer video on RADWIN Jet Beamforming
  - https://youtu.be/r6X_gZrgY_0

### 1.2.3 Client Premises Equipment(CPE) Technology Deployed.

RADWIN's powerful Subscriber Unit (SU) deliver fibre-like connectivity with high Packet-Per-Second (PPS) processing power to maintain the highest capacity even in small packet applications.

RADWIN's proprietary PtMP system ensures that RADWIN custom design of it's hardware and software ensures unrivalled performance.

Also designed for low visual impact, RADWIN's ruggedized SUs assure long-lasting operation even in the harshest conditions.

The RADWIN SU features include:

- SU-AIR: Up to 100Mbps
- SU-PRO: Up to 500Mbps
- 16 / 22dBi integrated antenna
- High durability – IP67 enclosure
- Compatible with all RADWIN base stations
- SU AIR: Designed for residential subscribers (best effort)
- SU PRO: Offers SLA for enterprise and bandwidth demanding applications, based on CIR

RADWIN SU-AIR 100 Series

- PDF Datasheet "RW-5H00-2A54.pdf"

## 1.3.Backhaul Network Technology and specification of Backhaul Technologies

Our Backhaul is heavily dependent on Fiber. We use high Capacity FDD Links to transfer bandwidth from a fibre POH to a high site.

### 1.3.1 Short Range Radio Backhaul Network Technology

We make use of high frequency narrow beam links to bridge short gaps between fibre POHs and high sites. We make use of 17GHz / 24GHz / 60GHz License Exempt bands and Licenced bands for delivery of bandwidth from site to site or from Fibre POH to Site. We also deploy 5.8GHz GPS Synced Backup Backhaul to cover Extreme Weather Events that may affect Higher Frequency Links.

- We utilise 60GHz MikroTik 60GLHG for links less than 1.25km delivering 2Gb/s HDX which has 4 channels available for future expansion and redundancy.
  - https://i.mt.lv/cdn/rb_files/LHGG-60ad-190611115231.pdf
- SIAE Microelettronica ALFOplus 80HD 80GHz 2Gbps FDX FDD Licenced Radio Link
  - "ALFOplus80HD Datasheet.pdf"
- SIAE Microelettronica ALFOplus 80HDx 80GHz 10Gbps FDX FDD Licenced Radio Link
  - "ALFOplus80HDx Datasheet.pdf"
- SIAE ALFOplus 17/17GHz 500Mbps FDD FDX Radio Link for Links up to 10km
  - "ALFOplus Datasheet.pdf"
- Ubnt Airfiber 24HD 24GHz 1Gb/s FDX FDD Radio Link up to 6Km
  - https://www.ui.com/downloads/datasheets/airfiber/airFiber_DS.pdf

All of these connections allow for increased bandwidth for our customers, we monitor the usage and as soon as usage on any of these links are regularly and consistently over 75% we start a procurement process to upgrade the links, this is ensured that upgrades either soft or hard are implemented in time so as to keep our capacity always 20% above of Peak Demand. We monitor our usage using various SNMP graphing and Latency Testing Tools in our NMS system.

### 1.3.2 Long Range Licensed Radio Backhaul Network Technology

- SIAE Microelettronica ALFOplus2 6-42GHz 2+0 XPIC 2Gbps Licensed Radio
    - "ALFOplus2 Datasheet.pdf"
- SIAE ALFOplus 6-42GHz 500Mb/s FDX Licenced Radio Link
    - "ALFOplus Datasheet.pdf"

All of these connections allow for increased bandwidth for our customers, we monitor the usage and as soon as usage on any of these links are regularly and consistently over 75% we start a procurement process to upgrade the links, this is ensured that upgrades either soft or hard are implemented in time so as to keep our capacity always 20% above of Peak Demand. We monitor our usage using various SNMP graphing and Latency Testing Tools in our NMS system.

### 1.3.3 Wired / Fibre Backhaul Network Technology

For sites and POPS that have 10Gb/s + Capacity we utilise the following routers to forward traffic onto High sites via the Radio Point to Point links described earlier

- Mikrotik CCR1072-1G-8S+ with a forwarding capacity of 50Gb/s
    - https://i.mt.lv/cdn/rb_files/CCR1072-1G-8Splus-1564987483.pdf

- Mikrotik CCR running on an X86-64 Server Hypervisor with a forwarding capacity Defined by the NUMA & PCI-E architecture of the Virtualization Hardware 40Gb/s +
    - https://i.mt.lv/pdf/software_chr.pdf

- Juniper VMX running on an X86-64 Server Hypervisor with a forwarding capacity Defined by the NUMA & PCI-E architecture of the Virtualization Hardware 40Gb/s +
    - https://www.juniper.net/assets/us/en/local/pdf/datasheets/1000522-en.pdf
- BSDRP and FRR running on X86-64 Server Hypervisor with a forwarding capacity Defined by the NUMA architecture of the Virtualization Hardware 40Gb/s +
    - https://bsdrp.net/features
- OpenBSD OpenBGPd Control plane X86-64 Server Hypervisor with a forwarding capacity Defined by the NUMA & PCI-E architecture of the Virtualization Hardware 40Gb/s +
    - https://OpenBSD.org
- Cisco Cloud Services router 1000V running on
    - https://www.cisco.com/c/en/us/products/collateral/routers/cloud-services-router-1000v-series/datasheet-c78-733443.html

For sites with 10G+ we use the following switches

- UBNT Edge Switch ES-16-XG 16 port 10G switch
    - https://www.ui.com/downloads/datasheets/edgemax/EdgeSwitch_ES-16-XG_DS.pdf

For smaller POPs and for POPS with PoE demands we deploy the following schedule of equipment

- Mikrotik RB1100AHx4 Router with a capacity for Routing up to 4Gb/s
    - https://i.mt.lv/cdn/rb_files/RB1100Dx4-171013102032.pdf

- Mikrotik Cloud Core CCR1016-12G Router
    - https://i.mt.lv/cdn/rb_files/ccr1016-12G-190612120511.pdf
- Mikrotik Cloud Core CCR1016-12G Router for routing up to 4Gb/s
    - https://i.mt.lv/cdn/rb_files/ccr1016-12G-190612120511.pdf
- Mikrotik RB4011iGS Router for capacity for routing up to 4Gb/s
    - https://i.mt.lv/cdn/rb_files/RB4011-RM-180919132428.pdf
- Ubiquiti Edgerouter Pro with a capacity for routing for Routing up to 4 Gb/s
    - https://www.ui.com/downloads/datasheets/edgemax/EdgeRouter_DS.pdf

### 1.3.2 Backhaul Network Technology (National, and Metro) and the specification of the Backhaul Providers

We have several Circuits from national backhaul provider partners – euNetworks, Eir, enet, Virgin Media

***Classified***

### 1.3.3 External Edge Capacity

We have an External Edge capacity of 40 GB/s

We have one 10G IP Transit from Cogent

We have one 10G IP Transit from Blacknight

We have one 10G interconnect with INEX LAN1

We have one 10G interconnect with INEX LAN2

All of these connections allow for increased bandwidth for our customers, we monitor the usage and as soon as usage on any of these links are regularly and consistently over 75% we start a procurement process to upgrade the links, this is ensured that upgrades either soft or hard are implemented in time so as to keep our capacity always 20% above of Peak Demand. We monitor our usage using various SNMP graphing and Latency Testing Tools in our NMS system.

## 1.4. Design for the national backhaul network including any traffic and capacity assumptions

The Backhaul network we have built has been designed around using quality backhaul from providers with an SLA that is appropriate for what are considered arterial paths for our network.

We use [5] Links spread across [4] providers from Datacentres in Urban Population centres to provincial towns around our network. From these provincial towns we utilise our own infrastructure built with high capacity ethernet radio links to get the bandwidth up to the nearest high site. We design the Radio links with adequate fade margins to achieve 99.99% availability. Where feasible

We introduce redundant paths between high sites using radio links so that if there is a fibre break in one provincial town we can fail over via a number of radio links to a fibre link in another provincial town. We also supplement our primary high speed backhaul connections with backup connections over gepon fiber connections as a backup of last resort.

## 1.5. The Specification of all types of Customer Premises Equipment which the operator (i) is using (ii) plans to use (if not already NGA). [CPE's only unless fibre]

Mikrotik

- RBSXTsq5nD
  - https://i.mt.lv/cdn/rb_files/SXTsq_Lite5-170927120250.pdf
- RBSXTsqG-5acD
  - https://i.mt.lv/cdn/rb_files/SXTsqplus5plusac-171208141935.pdf

Ubiquiti

- PBE-M5-400
  - https://www.ui.com/downloads/datasheets/powerbeam/PowerBeam_DS.pdf
- PBE-M5-300
  - https://www.ui.com/downloads/datasheets/powerbeam/PowerBeam_DS.pdf

All above devices will be replaced with Radwin devices. This process should be finished by end of 2020.

## 1.6. Coverage data as illustrated in the form of Polygonsed Data set

NOTE FOR INFORMATION/GUIDANCE – TO BE REMOVED WHEN COMPLETING THIS DOCUMENT

Attached as CSV and KML files

[WiFiber_NGA_Detail.pdf]

### 1.6.1 Table of Location of Base stations

List of Base stations that were used in wirelesscoverage.com WISDM LIDAR Line of Sight analysis software.

### 1.6.1a Location of Base stations as illustrated in a MAP

List of Base stations that were used in wirelesscoverage.com WISDM LIDAR Line of Sight analysis software.

[reference SiteCollection.pdf]

### 1.6.2 Table of Location of Connected Clients (eircodes only or GPS coordinates)

List of Connected customers in the form of EIRCODE or GPS Coordinates .

### 1.6.3 Table of Location of Covered Premises Physically Tested on Site (eircodes only or GPS coordinates)

List of sites where we have been on site to conduct Line of Sight surveys and have verified that we can give a connection in the form of EIRCODE or GPS Coordinates

Confidential

### 1.6.4 Table of Location of Premises Passed based on High Resolution LIDAR and DSM data (eircodes only or GPS coordinates)

[reference WiFiber_NGA_eircodes_.pdf]

## 1.6.4 LIDAR LOS testing and Methodology

We have engaged WirelessCoverage.com to build a Digital surface model based on high quality LIDAR / DSM data. We have supplied Wirelesscoverage.com a list of Sites and height of sectors to produce a list of premises that would be covered with clear line of sight

### Approach according to WirelessCoverage.com

The approach used for this project was designed to be as comprehensive and detailed as possible, using the best quality data and modelling tools available.

Detailed data was prepared to perform this analysis comprising of: -

- The latest EIRCODE dataset, purchased in August 2019
- A Digital Surface Model (DSM) for the whole country from Bluesky International, who have the most contemporary dataset currently available. They hold data at 1m resolution, which was scaled to 2.5m resolution using a bilinear interpolation method. Where any gaps in their coverage were identified SRTM data was used and interpolated to avoid any hard edges in the height data. More information on the data is available in Appendix A.
- Mast Site Data from our ISP

- WISDM Wireless Modelling system, which performs detailed line of sight tests between all properties and all tower sites. Further details on the WISDM Line of Sight Engine are included in Appendix C.

## Method according to WirelessCoverage.com

Data from our ISP was collected in September 2019 and imported into WISDM. Sites were classified as Standard or NGA and we also gathered details on future planned sites. The distinction between Standard and NGA sites is based upon the quality and style of equipment currently installed at these sites, along with the backhaul feeds. Those classified as NGA are capable of connecting premises at NGA speeds of 30Mbps download.

Using WISDM, wirelesscoverage ran several coverage passes to all EIRCODE centroids: -

1. All Sites from our ISP at NGA
2. All Sites from our ISP at non-NGA

Within each pass, WISDM takes each Site within the test and performs a Wireless Line of Sight test to each property within a given radius. It is important to note that a Wireless Line of Sight Test differs from an optical test, as it takes into account the Fresnel 1 Zone around the direct (optical) path. This is a more robust means of determining line of sight. In this exercise, we discounted all properties that had more than 15% Fresnel 1 incursion, and therefore does not include properties with Near Line of Sight, which in many cases could successfully be connected.

Where a property does have Wireless Line of Sight, it is excluded from further tests within that pass, in order to avoid double-counting properties.

We then performed analysis of the coverage list from each operator with NGA coverage to identify those properties that could receive NGA service from more than one operator.

## NGA Assumptions

Due the variety of equipment mounted at each site for different operators, we have taken a cautious approach to whether a site is capable of delivering NGA speeds. As such, we have taken a worst-case assumption of the type of equipment used for access points or base stations.

We considered the signal level that would be required to get the full modulation rates on the most basic of commonly installed fixed wireless equipment, as well as a significant fade margin. Assuming a nominal operating frequency of 5.7 GHz with regulatory compliant power output (EIRP) from a base station of 33 dBm (2 Watts) and a client receiver with 30cm diameter antenna providing 23 dBi gain, the receive signal level (RSL) with clear line of sight would be -70.1 dBm at 7.5 km. Using a basic radio system, such as the Ubiquiti Rocket M5 access points and associated M5 customer receiver such as NanoBeam M5 system on a 20 MHz channel, and an assumed noise floor of 90 dBm, a client would connect at MCS13, providing a physical interface rate of 104 Mbps and a typical throughput rate of approximately 54 Mbps, which is safely above the NGA threshold and leaves a considerable fade margin assuming the access point is not over-subscribed.

# Assumptions and Constraints

As with all modelling approaches to wireless coverage, there are factors which could over-state or under-state coverage. Here is a summary of the key factors as they relate to this project: -

## Over-statement factors

- A small percentage of the national map data used was derived from low-resolution (10 to 30m) data, which could mean that obstructions to the wireless signal path calculations were missed. We estimate an error rate of <2% over-statement.
- Since the high-resolution data was produced between 2015 and 2017, it is likely that additional tree growth and new building works will have occurred in the intervening period which means that some wireless paths are now blocked. We estimate a resultant over-statement of <1% from this.
- Whilst it may be possible to receive a high-quality signal at a given property, it is possible that there is no suitable location on the property to mount a receiver due to the construction or location of the property. For example, waterside properties or those with unusual construction such as all-glass exterior can be very challenging.

## Under-statement factors

- In this exercise, we performed single-point line of sight tests to each EIRCODE property. In reality, it is possible that the Wireless Line of Sight to that one point may be obscured and therefore reported as no coverage, but if a receiver was mounted at a different point on the property, a connection could be established. We estimate an under-statement of 3-4% from this factor.
- We used a watershed method for wireless line of sight calculation which allows for little or no Near Line of Sight connections. Many modern radio systems using the diversity associated with MIMO transmission allows for high quality connections to be established in Near Line of Sight operation and these have not been incorporated in the model. This is estimated to have an affect of <10%, but it is highly dependent on the technology used by the operator.
- We have assumed that 30cm dishes are used at the customer property to achieve an appropriate signal level. It is common practice to install 40cm dishes or larger, which have higher gain and therefore can receive a good signal at a longer range. Using larger dishes could increase the coverage from each access point substantially.

## Multi Dwelling Units (MDUs)

WISDM currently has a design constraint which means that the premises counted in coverage checks shows the same EIRCODE for all properties that have the same physical location (ie. Multi-dwelling units). This means that the coverage lists appear to have duplications. It was not possible to resolve this issue in the time available to complete the project.

LIDAR DSM Data Source coverage according to wirelesscoverage.com

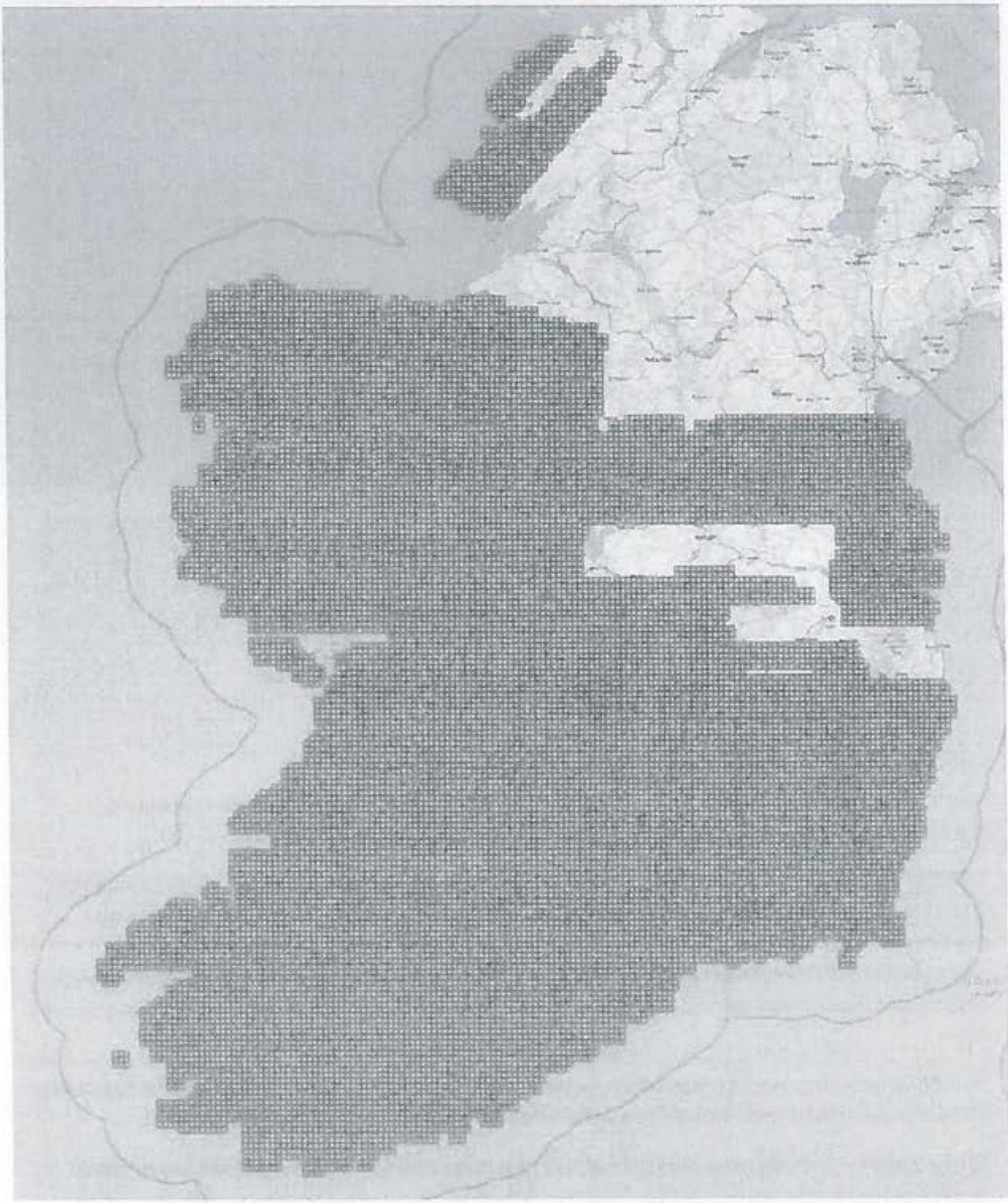


*Figure 1. Map of 1m DSM Data from Bluesky International, collected between 2015 and 2017*

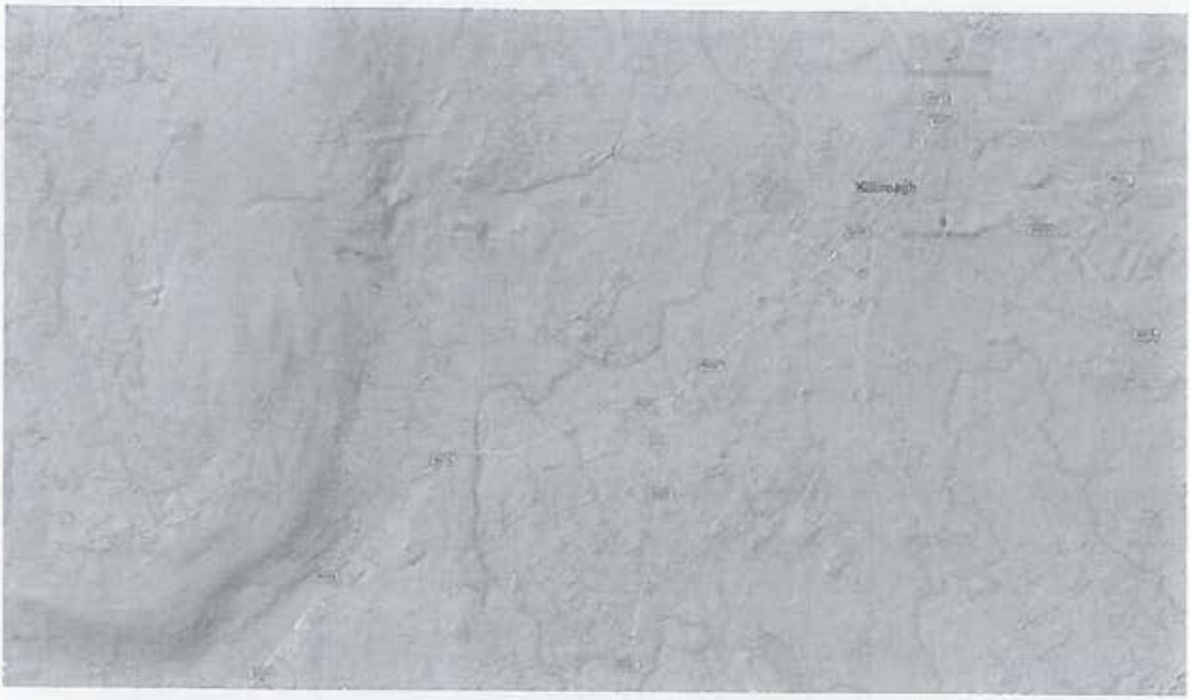


*Figure 2. Example render of DSM Data showing trees, buildings and other surface features.*

## Wirelesscoverage.com WISDM™ Line of Sight Engine

### Highlights

Wireless coverage WISDM comprises of a family of ultra-high performance wireless planning systems developed by Boundless Networks Ltd.

WISDM WISP Edition is an interactive planning and design system built to facilitate the creation of scalable, robust and performant fixed wireless networks for Wireless IPSs. It enables the rapid creation of 'Ideal' wireless networks over very large areas of thousands of square kilometres. It is well suited to rural expanses as well as mixed and urban environments too. Once an Ideal network has been designed, the network can be fine-tuned to consider build constraints and resiliency in real time.

WISDM can also be used to analyse the coverage of an existing wireless network and perform 'what-if' tests to plan ad-hoc extensions to a network to verify potential coverage and backhaul.

Using WISDM, a predictable coverage model can be prepared in hours and **detailed coverage of individual properties** can be predicted with an extremely high level of accuracy. Site planning and acquisition is accelerated by use of the interactive planning tools, allowing rapid decisions about mast location to be made with instant coverage impact reporting.

### Overview

WISDM comprises of several components and processes to complete the overall solution. At the heart of the system is a very high performance wireless Line of Sight (LoS) calculation engine. The

LoS engine can calculate over 150 million wireless line of sight tests per second and can use a wide variety of terrain and surface obstruction data sets at any resolution.

Overall, WISDM WISP Edition performs the following tasks: -

1. Site Finder. This creates an 'Ideal' list of sites where masts could be located for optimum coverage for a given number of target premises passed from a target premises dataset. Target premises can be a list of all properties from a comprehensive source, such as Ordnance Survey AddressBase, or a subset of premises in say, a Government Intervention area. Assumptions can be used to set mast profiles which would include mast height and effective wireless range. For example, the Site Finder can be run with parameters which state that 20 locations could be built with 30m towers, then calculate how many 15m towers would be needed to pass a certain quantity of target premises.
2. Backhaul Modelling. The Backhaul Modeller analyses a Site Location dataset and performs line of sight tests between them to create microwave backhaul. Assumptions can be used to help plan for the style of links to be used. For example, links up to 5km can be coloured differently than links from 5km to 17km. This helps when planning a network that has optimum resilience, performance and operating costs due to the potential costs incurred to run licensed microwave links or fibre backbone.
3. Wide Area Network (WAN) Visualizer. The WAN Visualizer provides full-screen mapping to allow users to see the overall shape of a network and the distribution of different sized towers and backhaul connections between sites. The WAN Visualizer can be called from the Site Coverage and Modelling system.
4. Site Coverage and Modelling System. This is an interactive web-based tool that allows planners to review the calculated Ideal Sites and move them on a map. At each point, the user can see instantly the impact of changes to coverage of Target Premises, as well as backhaul connections to other sites.
5. Backhaul Link Capacity Planning. Backhaul links can be described in terms of capacity and latency. Client connection volumes can also be applied to sites and WISDM will predict traffic load and volumes relative to transit or fibre injection points.

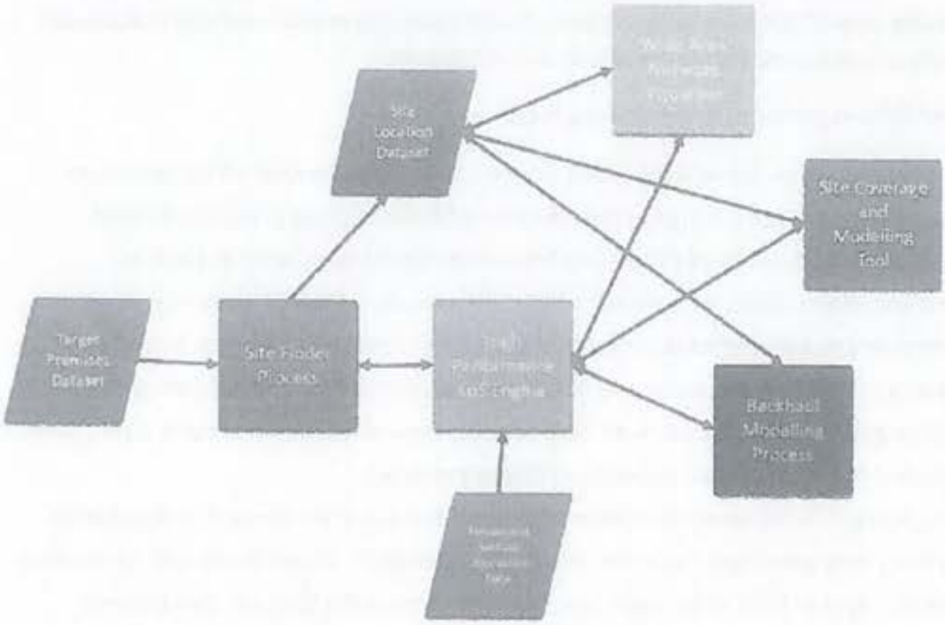



FIGURE 1 WISDM SCHEMATIC SYSTEM OVERVIEW

## Wirelesscoverage.com WISDM LoS Engine

The WISDM LoS Engine is a custom-built high performance wireless propagation calculator developed in Native C and CUDA. It is a multi-threaded application, currently running on a server farm at Wireless Coverage and is accessed via a C API. This currently operates with 5,000 GPU cores to achieve around 500 million line of sight transactions per second when creating viewsheds but can be scaled further as required.

The LoS Engine has forward and reverse lookup features that are optimised to illustrate coverage from a single point, or supply from multiple points. These features are so fast that they can be operated in real time and take into consideration precision line of sight calculations as well as frequency, loss (according to ITU recommendations) and 3d antenna patterns for both transmitter and receiver.

### Line of Sight Engine Technical Overview

Specific variants of the Line of Sight Engine exist for Forward (Viewshed) and Reverse (Best AP) coverage over large areas at any sample resolution. Below is an example of point to point request, but this is replicated over larger areas for the Forward and Reverse viewshed methods, where a map grid is also specified. The application uses the following parameters as input to each request via an API: -

- Site A Lat/Lon
- Site A transmitter height above ground in metres
- Site A transmitter power dBm
- Site A transmitter antenna gain in dBi
- Transmit frequency in MHz
- Scanning resolution in metres
- Site B Lat/Lon
- Site B receiver height above ground in metres
- Site B receiver antenna gain in dBi
- Percentage of first Fresnel required for partial line of sight in %
- Percentage of first Fresnel required for no line of sight in %
- Antenna Model (used for beam pattern)

The response for each request includes the following: -

- Link distance in metres
- Pass Status (Full Line of Sight, Partial Line of Sight or No Line of Sight)
- Predicted Receive Signal Strength (RSL) in dBm, assuming full Line of Sight
- Azimuth from Site A in degrees from true North
- Azimuth from Site B in degrees from true North
- Elevation from Site A in degrees
- Elevation from Site B in degrees
- Antenna Model (used for beam pattern)
- Optional link ground profile .PNG image file, illustrating the link profile and first Fresnel shape

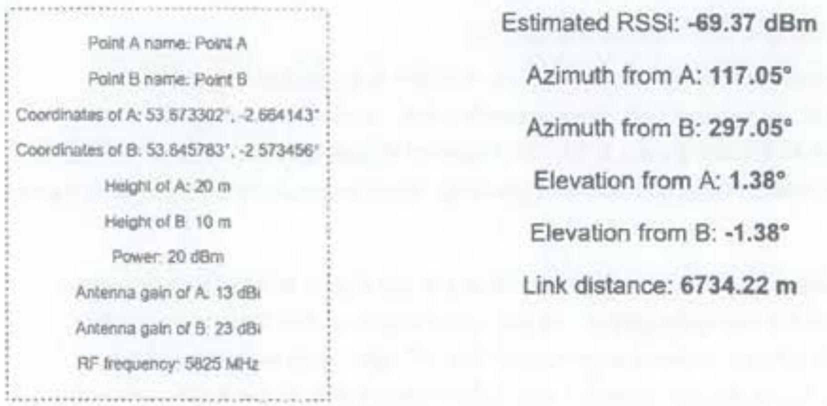



**FIGURE 2 SAMPLE LOS ENGINE INPUT AND OUTPUT**

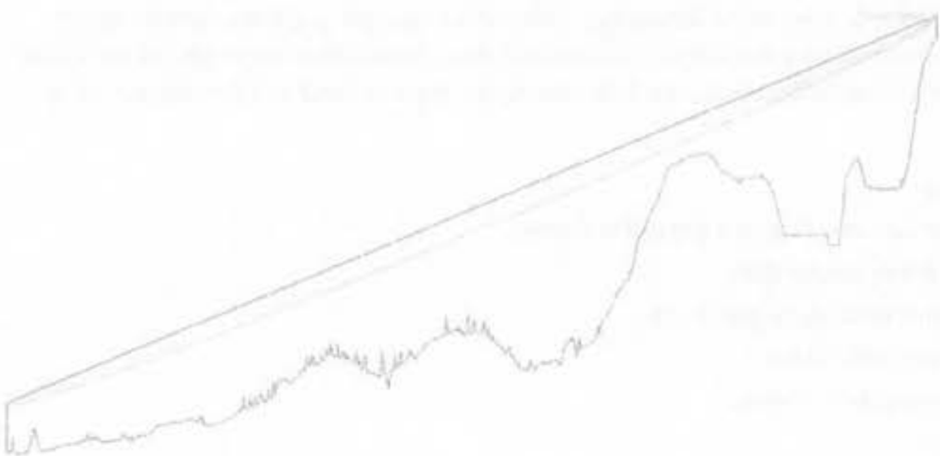


**FIGURE 3 SAMPLE LOS GROUND PROFILE IMAGE**

## Mathematical and Technical LoS Model

A DSM elevation raster (of chosen resolution) of the target area is loaded into memory (~11GB GeoTIFF file equates to around 6,500 sq miles, imported with GDAL C library) into a flat array of 32-bit floats in a geodetic WGS84 latitude / longitude grid. This stays loaded in memory for every call of the function. A function exists to return the height in metres above sea level for any given latitude + longitude using bilinear interpolation in the grid. This allows for very fast indexed surface elevation lookups for any point in target area with high resolution.

64-bit integers are used for indexing coordinates and x87 80-bit floating-point numbers are used in coordinate calculations.

2 functions exist, geodetic_to_ecef and ecef_to_geodetic for converting between ellipsoidal WGS84 coordinates and cartesian ECEF coordinates.

geodetic_to_ecef is an implementation of Section 10.2.1 from B. Hofmann-Wellenhof, H. Lichtenegger, J. Collins' GPS - theory and practice as follows:

$$
\begin{aligned}
N(\phi) &= \frac{a^2}{\sqrt{a^2\cos^2\phi + b^2\sin^2\phi}} \\
X &= (N(\phi) + h)\cos\phi\cos\lambda \\
Y &= (N(\phi) + h)\cos\phi\sin\lambda \\
Z &= \left(\frac{b^2}{a^2}N(\phi) + h\right)\sin\phi
\end{aligned}
$$

where *h* is height in metres; ϕ is latitude; λ is longitude; *a* is the Earth's equatorial radius in metres; *b* is the Earth's polar radius in metres; *(X,Y,Z)* is the cartesian ECEF coordinate.

ecef_to_geodetic is an implementation of J. Zhu's "Exact conversion of earth-centred, earth-fixed coordinates to geodetic coordinates" formula as follows:

$$
\begin{aligned}
r &= \sqrt{X^2 + Y^2} \\
E^2 &= a^2 - b^2 \\
F &= 54b^2Z^2 \\
G &= r^2 + (1 - e^2)Z^2 - e^2E^2 \\
C &= \frac{e^4Fr^2}{G^3} \\
S &= \sqrt[3]{1 + C + \sqrt{C^2 + 2C}} \\
P &= \frac{F}{3\left(S + \frac{1}{S} + 1\right)^2G^2} \\
Q &= \sqrt{1 + 2e^4P} \\
r_0 &= \frac{-(Pe^2r)}{1 + Q} + \sqrt{\frac{1}{2}a^2(1 + 1/Q) - \frac{P(1 - e^2)Z^2}{Q(1 + Q)} - \frac{1}{2}Pr^2} \\
U &= \sqrt{(r - e^2r_0)^2 + Z^2} \\
V &= \sqrt{(r - e^2r_0)^2 + (1 - e^2)Z^2} \\
Z_0 &= \frac{b^2Z}{aV} \\
h &= U\left(1 - \frac{b^2}{aV}\right) \\
\phi &= \arctan\left(\frac{Z + e'^2Z_0}{r}\right) \\
\lambda &= \operatorname{arctan2}(Y, X)
\end{aligned}
$$

where *(X,Y,Z)* is the cartesian ECEF coordinate; *h* is height in metres; ϕ is latitude; λ is longitude; *a* is the Earth's equatorial radius in metres; *b* is the Earth's polar radius in metres; *e* is the Earth's first orbital eccentricity; $e'$ is the Earth's second orbital eccentricity.

The 3D cartesian coordinates of each radio is found by sampling the ground elevation of the two points and adding on the mast heights, and then using geodetic_to_ecef. The accurate straight-line distance between the two radios can be found by using $\sqrt{dx^2 + dy^2 + dz^2}$.

The straight line between each *(x,y,z)* position is divided into linear interval points at the desired scan resolution. These points are then converted back into (latitude, longitude, height) WGS84 coordinates using ecef_to_geodetic.

The surface elevation at each of these WGS84 points is sampled and the resulting coordinates + height are converted back into ECEF coordinates.

The resulting 3D ECEF coordinates should mostly be in a flat plane and represent the elevation profile of the terrain under the line between the two radios, including the curvature of the Earth.

These coordinates are transformed into flat 2D coordinates by rotating them through 3 axes using transformation matrices. Once they are rotated to a flat plane against the axes, the resulting *Z* coordinate will be approximately zero and is discarded to produce 2D coordinates.

A 2D straight line is plotted between the two radio coordinates and perpendicular to this line, points are calculated and plotted for the first Fresnel zone and given threshold percentages within the Fresnel zone. The radius *r* in metres of the first fresnel zone is calculated using:

$$r = \sqrt{\frac{cd(t-d)}{1000000ft}}$$

where *c* is the speed of light in $ms^{-1}$; *d* is the distance along the line in metres; *t* is the total distance between the two radios; *f* is the frequency in megahertz.

Intersection with the surface profile polygon and the plotted Fresnel threshold points is tested using binary search + linear interpolation.

The basic RSL *s* in decibels is calculated using:

$$l = 92.5 + 20\log_{10}\left(\frac{d}{1000}\right) + 20\log_{10}\left(\frac{f}{1000}\right)$$
$$s = p + g_1 + g_2 - l - t$$

where *l* is the free-space path loss in decibels; *d* is the distance in metres; *f* is the frequency in megahertz; *p* is the power of the transmitter; *g1* and *g2* are the antenna gains of each antenna; *t* is the transmission line loss, assumed to be 1 decibel. Further ITU-R attenuation models are applied for appropriate bands, but not described in this document.

# WIRELESS COVERAGE REPORT
# REPUBLIC OF IRELAND

30 September 2019

[redacted]
Wireless Coverage Ltd

# CONTENTS

## INTRODUCTION

This report was prepared at the request of 28 Wireless Internet Service Providers in the Republic of Ireland.

Many of the Irish Wireless Internet Service Providers stated that they had significant concerns about the NBP duplicating state aid spend on new infrastructure where private operators had already deployed infrastructure that is delivering NGA speeds to customers throughout the proposed intervention area. The ISPS embarked on a project where they spent a lot of time and effort in documenting their site locations. The ISPs wanted to demonstrate with as much scientific rigour as possible the number of houses passed by their significant investment in broadband infrastructure throughout Ireland and indeed the proposed NBP intervention area. Operators would like to see the NBP harness this private investment already made, which would deliver far higher value for the public purse.

A detailed analysis of the broadband coverage of each operator was undertaken using state of the art wireless modelling system, WISDM. The results are a comprehensive coverage map, and list of premises past using the best software and LIDAR data available.

## APPROACH

The approach used for this project was designed to be as comprehensive and detailed as possible, using the best quality data and modelling tools available.

Detailed data was prepared to perform this analysis comprising of: -

- The latest EIRCODE dataset, purchased in August 2019
- A Digital Surface Model (DSM) for the whole country from Bluesky International, who have the most contemporary dataset currently available. They hold data at 1m resolution, which was scaled to 2.5m resolution using a bilinear interpolation method. Where any gaps in the LIDAR/DSM coverage were identified, the following other Topographical data sources were used in the order of descending preference.
    - Open Topographic Lidar Data from the Irish Government
    - SRTM (Shuttle Radar Topography Mission)

  These data sets were blended and interpolated to avoid any hard edges in the height data. More information on the data is available in Appendix A.

- Mast Site Data as supplied by 28 Irish ISPs. The list of participating ISPs is included in Appendix B.
- WISDM Wireless Modelling system, which performs detailed line of sight tests between all properties and all tower sites. Further details on the WISDM Line of Sight Engine are included in Appendix C.

### METHOD

Data from 28 ISPs was collected in September 2019 and imported into WISDM. Sites were classified as Standard or NGA and we also gathered details on future planned sites. The distinction between Standard and NGA sites is based upon the quality and style of equipment currently installed at these sites, along with the backhaul feeds. Those classified as NGA were declared as capable of connecting premises at NGA speeds of 30Mbps download and 6Mbs upload.

Using WISDM, we ran several line of sight coverage passes to all EIRCODE centroids: -

1. All Sites from all operators at NGA
2. All Sites from all operators at non-NGA
3. All Sites from individual operators at NGA
4. All Sites from individual operators at non-NGA

Within each pass, WISDM takes each Site within the test and performs a Wireless Line of Sight test to each property within a given radius. It is important to note that a Wireless Line of Sight Test differs from an optical test, as it takes into account the Fresnel 1 Zone around the direct (optical) path. This is a more robust means of determining line of sight. In this exercise, we discounted all properties that had more than 15% Fresnel 1 incursion, and therefore does not include properties with Near Line of Sight, which in many cases could successfully be connected.

Where a property does have wireless line of sight, it is excluded from further tests within that pass, in order to avoid double-counting properties.

We then performed analysis of the coverage list from each operator with NGA coverage to identify those properties that could receive NGA service from more than one operator.

An additional process was also performed taking the individual NGA Coverage data for each ISP and counting the number of times each EIRCODE exists. Where the count is 2 or more, these were then added to a separate list of premises, along with the count of ISPs with coverage. This creates a list of premises that could access NGA from multiple participating ISPs.

During this exercise, approximately 80 billion line of sight calculations were performed in order to create the output data for this report.

## NGA Assumptions

Due the variety of equipment mounted at each site for different operators, we have taken a cautious approach to whether a site is capable of delivering NGA speeds. As such, we have taken a worst-case assumption of the type of equipment used for access points or base stations.

We considered the signal level that would be required to get the full modulation rates on the most basic of commonly installed fixed wireless equipment, as well as a significant fade margin. Assuming a nominal operating frequency of 5.7 GHz with regulatory compliant power output (EIRP) from a base station of 33 dBm (2 Watts) and a client receiver with 30cm diameter antenna providing 23 dBi gain, the receive signal level (RSL) with clear line of sight would be -70.1 dBm at 7.5 km. Using a basic radio system, such as the Ubiquiti Rocket M5 access points and associated M5 customer receiver such as NanoBeam M5 system on a 20 MHz channel, and an assumed noise floor of 90 dBm, a client would connect at MCS13, providing a physical interface rate of 104 Mbps and a typical throughput rate of approximately 54 Mbps, which is safely above the NGA threshold and leaves a considerable fade margin assuming the access point is not over-subscribed.

It is highly likely that most premises will be able to receive significantly above 30 Mbps and in some cases in excess of 100 Mbps. However, due to the diversity of equipment installed by different operators, we have not modelled this within the report.

# Coverage Results

## Total Coverage from Operators

| Criteria | Premises Passed |
|---|---|
| **Currently NGA Compliant** | **689,781** |
| **Currently NGA Compliant inside c540k intervention area (amber area)** | **TBC** |
| **Currently NGA Compliant inside c46k additional intervention area (purple area)** | **TBC** |
| **All Operators – NGA and Non-NGA Compliant** | **1,456,470** |
| **All Operators – NGA Compliant or NGA Planned** | TBC |
| **All EIRCODEs with Multiple Operator Coverage at NGA** | **140,084** |

Further details are included in Appendix C.

To aid with visualising the data for this submission WirelessCoverage.com have published a static reference to the submitted data in this report in an interactive map on a tileserver at the following location:

https://wisdm.wirelesscoverage.com/irish-nga-static-2019-09-30/

To access the map, the following credentials are required: -

Username wisdm
Password W8nxhpO0hR17sfDMZ14Y

The Map allows a user to visualise the following:

- Every premises covered with NGA broadband (green and yellow small dots) colour denotes distance from the mast, but all are within the 7.5 km/-71dBm contour.
- Every NGA enabled Site deployed by operators (Large Blue Dots)
- Every NGA premises Covered by 2 or more operators. (Purple dots)
- Worst cast NGA Coverage displayed as medium resolution Viewsheds limited to 7500m range from Operator site.

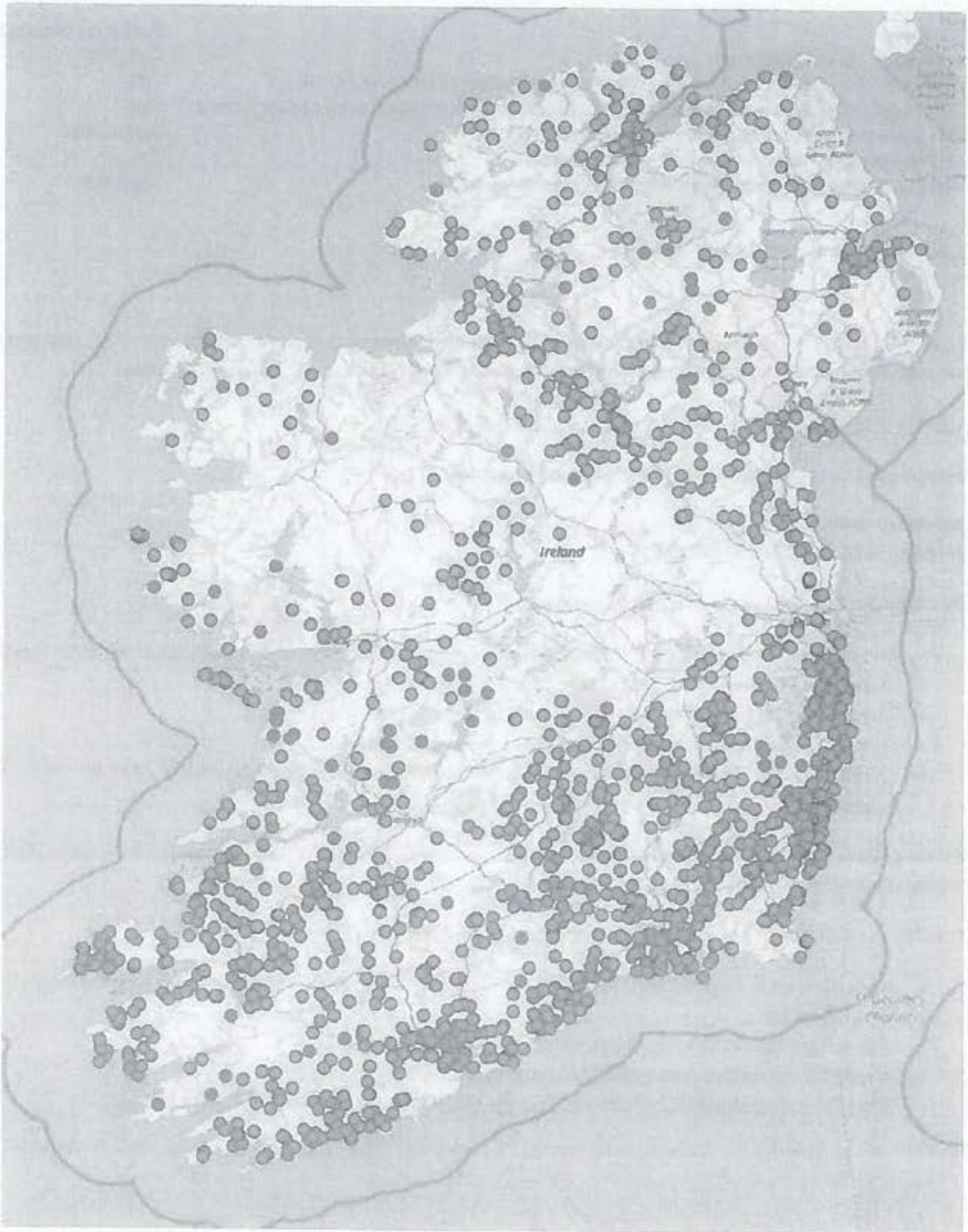
As other Irish ISPS onboard and consent to be included in the WISDM Wireless NGA map on the wirelesscoverage.com WISDM platform they will be included in the living map:

The URL for this is https://wisdm.wirelesscoverage.com/irish-nga-living/

- Every premises covered with NGA broadband (green and yellow small dots) colour denotes distance from the mast.
- Every NGA enabled Site deployed by operators (Large Blue Dots)
- Every NGA premises Covered by 2 or more operators. (Purple dots)
- Every Newly enabled NGA Premises (changes since 30th of September 2019 (Red Dots)

## ACCESS POINT SITE LOCATIONS

We surveyed coverage from 1,592 locations (1,456 in Ireland), using the access point mount-height, to each property location in the EIRCODE database.




Site Locations for all participating operators

## Assumptions and Constraints

As with all modelling approaches to wireless coverage, there are factors which could over-state or under-state coverage. Here is a summary of the key factors as they relate to this project: -

### Over-statement factors

- A small percentage of the national map data used was derived from low-resolution (10 to 30m) data, which could mean that obstructions to the wireless signal path calculations were missed. We estimate an error rate of <2% over-statement.
- Since the high-resolution data was produced between 2015 and 2017, it is likely that additional tree growth and new building works will have occurred in the intervening period which means that some wireless paths are now blocked. We estimate a resultant over-statement of <1% from this.
- Whilst it may be possible to receive a high-quality signal at a given property, it is possible that there is no suitable location on the property to mount a receiver due to the construction or location of the property. For example, waterside properties or those with unusual construction such as all-glass exterior can be very challenging.

### Under-statement factors

- In this exercise, we performed single-point line of sight tests to each EIRCODE property. In reality, it is possible that the Wireless Line of Sight to that one point may be obscured and therefore reported as no coverage, but if a receiver was mounted at a different point on the property, a connection could be established. We estimate an under-statement of 3-4% from this factor.
- We used a watershed method for wireless line of sight calculation which allows for little or no Near Line of Sight connections. Many modern radio systems using the diversity associated with MIMO transmission allows for high quality connections to be established in Near Line of Sight operation and these have not been incorporated in the model. This is estimated to have an effect of less than 10%, but it is highly dependent on the technology used by the operator.
- We have assumed that 30cm dishes are used at the customer property to achieve an appropriate signal level. It is common practice to install 40cm dishes or larger, which have higher gain and therefore can receive a good signal at a longer range. Using larger dishes could increase the coverage from each access point substantially.

## Multi Dwelling Units (MDUs)

WISDM currently has a design constraint which means that the premises counted in coverage checks shows the same EIRCODE for all properties that have the same physical location (ie. Multi-dwelling units). This means that the coverage lists appear to have duplications. It was not possible to resolve this issue in the time available to complete the project.

## Data Accuracy

Whilst every care has been taken in preparing this report, please note that the data accuracy of the output from this report is dependent on the quality of data provided to us and due to the exceptional time constraints on the project, Wireless Coverage has not performed a full rigorous validation on the data provided by: -

- The wireless ISPs data. (tower sites, height, existing or planned transmission equipment)
- EirCode (property location details)
- Bluesky International (Digital Surface Map) data
- Open LIDAR topographical data published by data.gov.ie
- SRTM Data published by NASA

That said, the NGA calculations have been performed using extremely conservative wireless signal and interference calculations and the results are generally completely in line with other projects of this type.

## Errors in NBP Maps

In the production of this report and the coverage counts, we encountered a number of issues with the integrity of the National Broadband Plan map data (Q119_Public_Blue_Amber). This polygonised data had 61 data errors where lines in the polygons crossed. These are shown in outline here...

These errors were corrected using a standard GDAL fix program, but it is possible that the coverage count in these polygons is not 100% accurate.

# APPENDICES

# APPENDIX A – DSM DATA

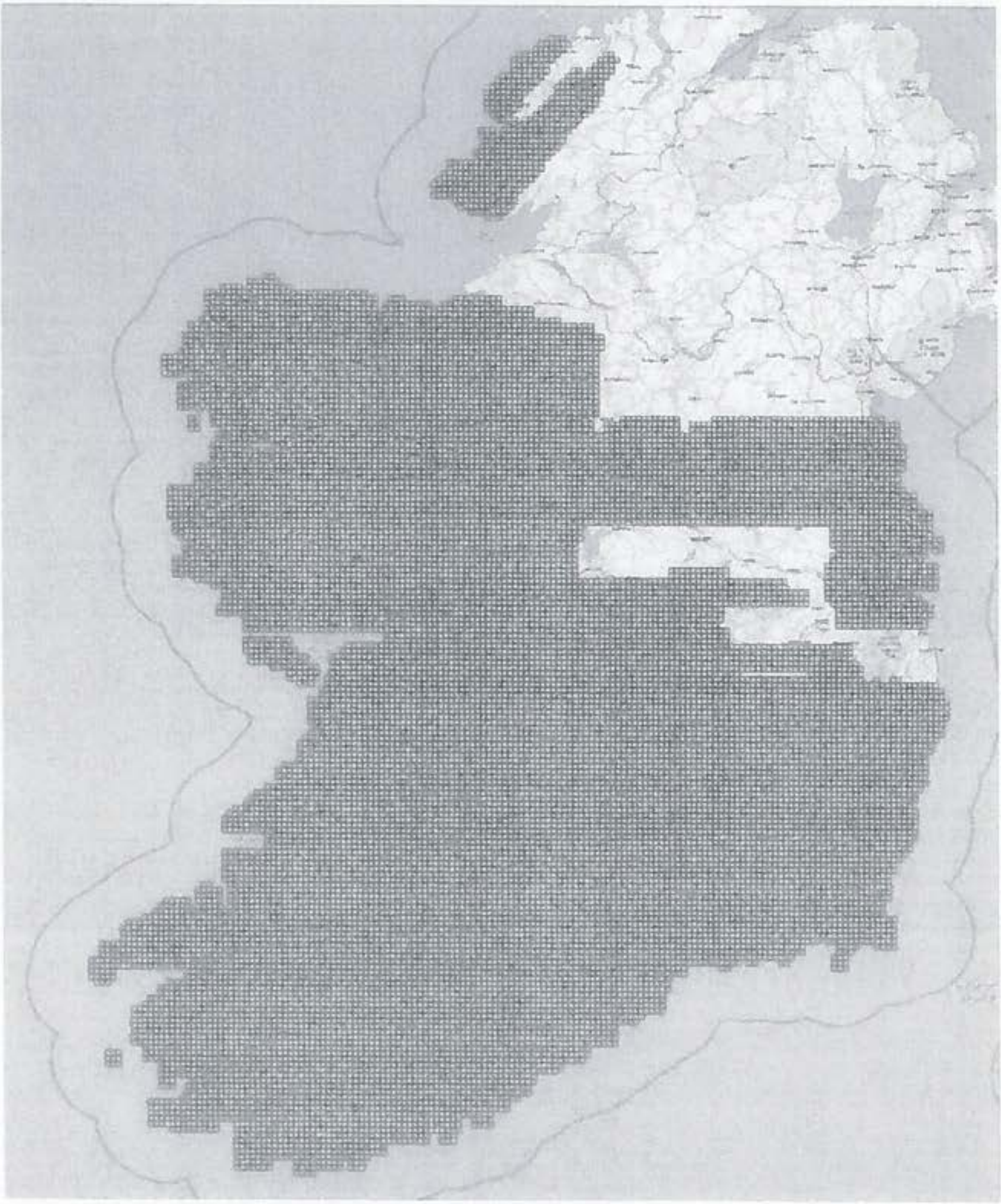


*Figure 1. Map of 1m DSM Data from Bluesky International, collected between 2015 and 2017*

*Figure 2. Example render of DSM Data showing trees, buildings and other surface features.*

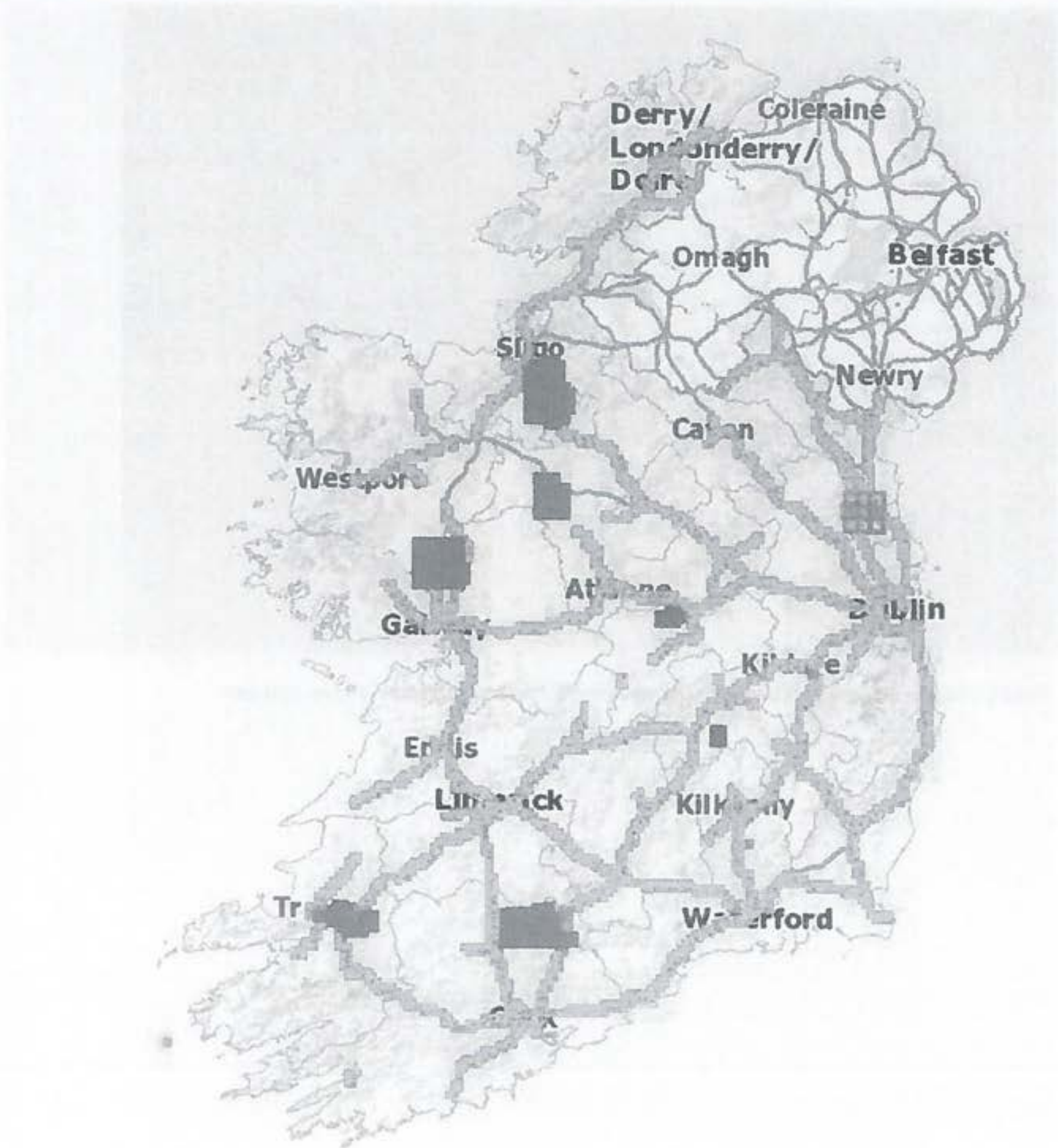



*Figure 3. Irish Government published Open LIDAR data areas that supplemented the propietary LIDAR data.*


*Figure 4. Example of Open Topographic LIDAR data detail as published on data.gov.ie*

*Figure5. SRTM topographical data as captured and rendered by NASA*

# Appendix B – Participating ISPs

The following ISPs have submitted detailed tower location and height data for their current networks. They have also identified which sites are NGA-capable now or are planned for upgrade to NGA-capability. Planned coverage is not included in this report.

**ISP Name (Alphabetic)**
Airwave Internet
AirWire
Alpha Wave
Aptus Broadband
Atlantek
BBNet
Bluebox
Cork Internet Exchange
Digital Forge
Eurona Brisknet
IverTec
KerNet Broadband
Kerry Broadband
LightNet
MTS Media
Munster Wireless
Net1
Nova Broadband
NuWave
Orion Digital Services Ltd.
Rapid Broadband
Real Broadband
Regional Broadband
Skytel Broadband
Total Wireless / HiSpeed
Whizzy Internet
WiFiber
Wireless Connect

## Appendix C – Coverage Data

Please note that due to commercial sensitivity of the operators involved, the names have been redacted and the data sorted by number of NGA premises passed in order to protect their identities. Each operator has the detailed coverage data available for their network, including the precise location of each access point site and the link distances to each EIRCODE with clear line of sight.

Detailed information regarding all potential connections and the individual operators is available under confidential disclosure agreement from Wireless Coverage Ltd. Please contact david@wirelesscoverage.com for further information.

| | NUMBER OF SITES | NGA PREMISES PASSED | NON-NGA PREMISES PASSED | NUMBER OF CLIENTS CONNECTED |
|---|---|---|---|---|
| TOTAL FOR 28 ISPS | 1,465 | 689,781 | 1,456,470 | 91,894* |

### Total Connected Properties

We estimate that the 28 ISPs who contributed to this report have a total of **91,894 live connections.**

In addition, two further operators provided connected customer counts totalling 5,300, taking the total estimated for 30 operators to 97,194 customers altogether. We are also aware of several other substantial wireless ISPs in Ireland, so the total market size could be substantially higher.

*This is based upon existing customer connection data supplied by 27 of the 28 ISPs, which totalled 76,705.

Across the 28 participating ISPs, approximately 6.5% of their premises passed are connected customers. This figure is in line with similar exercises conducted by Wireless Coverage in the UK on behalf of ISP's reporting into Ofcom for the Connected Nations Report. It is also in keeping with data provided by ISP's in Ireland who have chosen not to participate directly in this project.

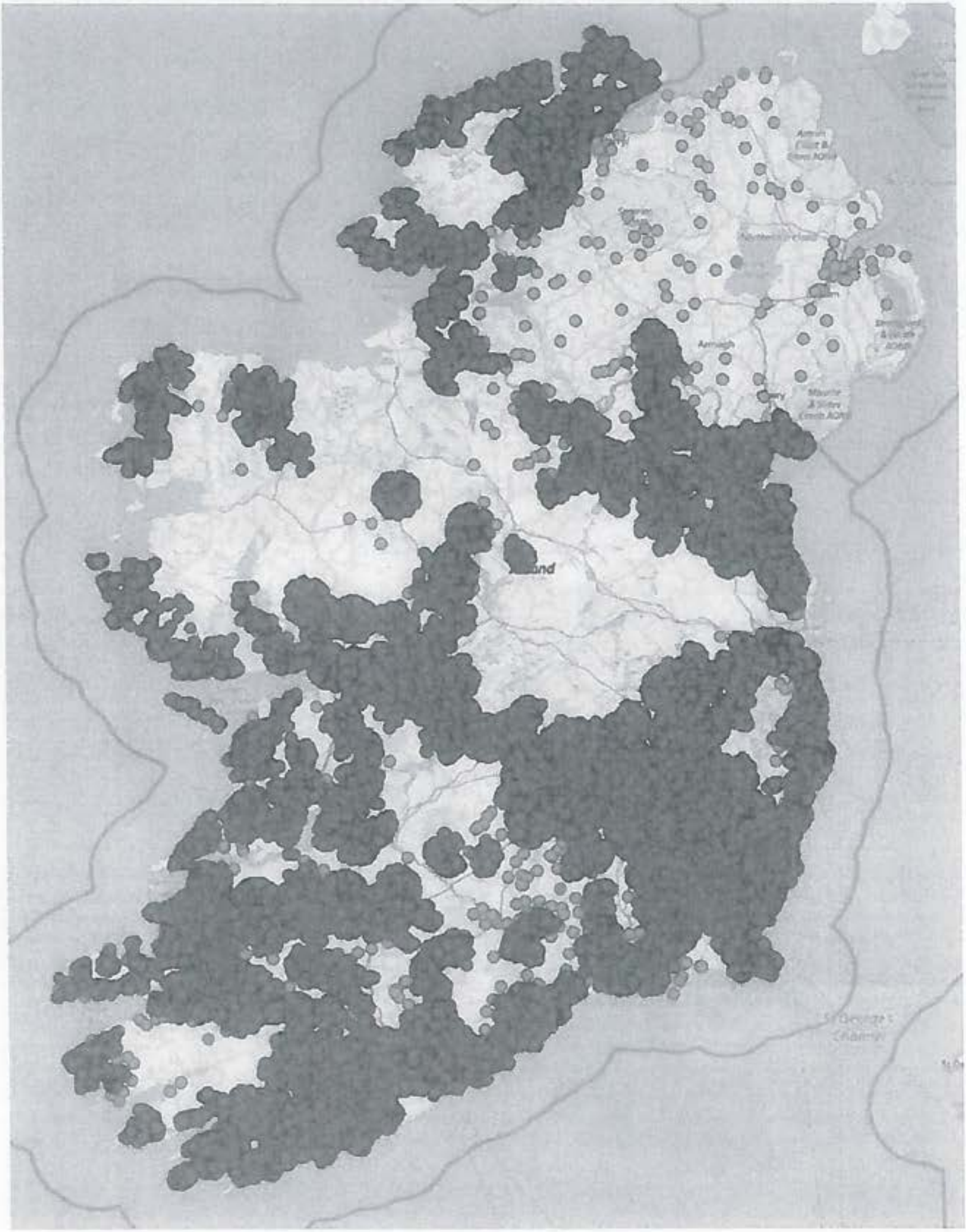


*Figure6. NGA Premises Passed*

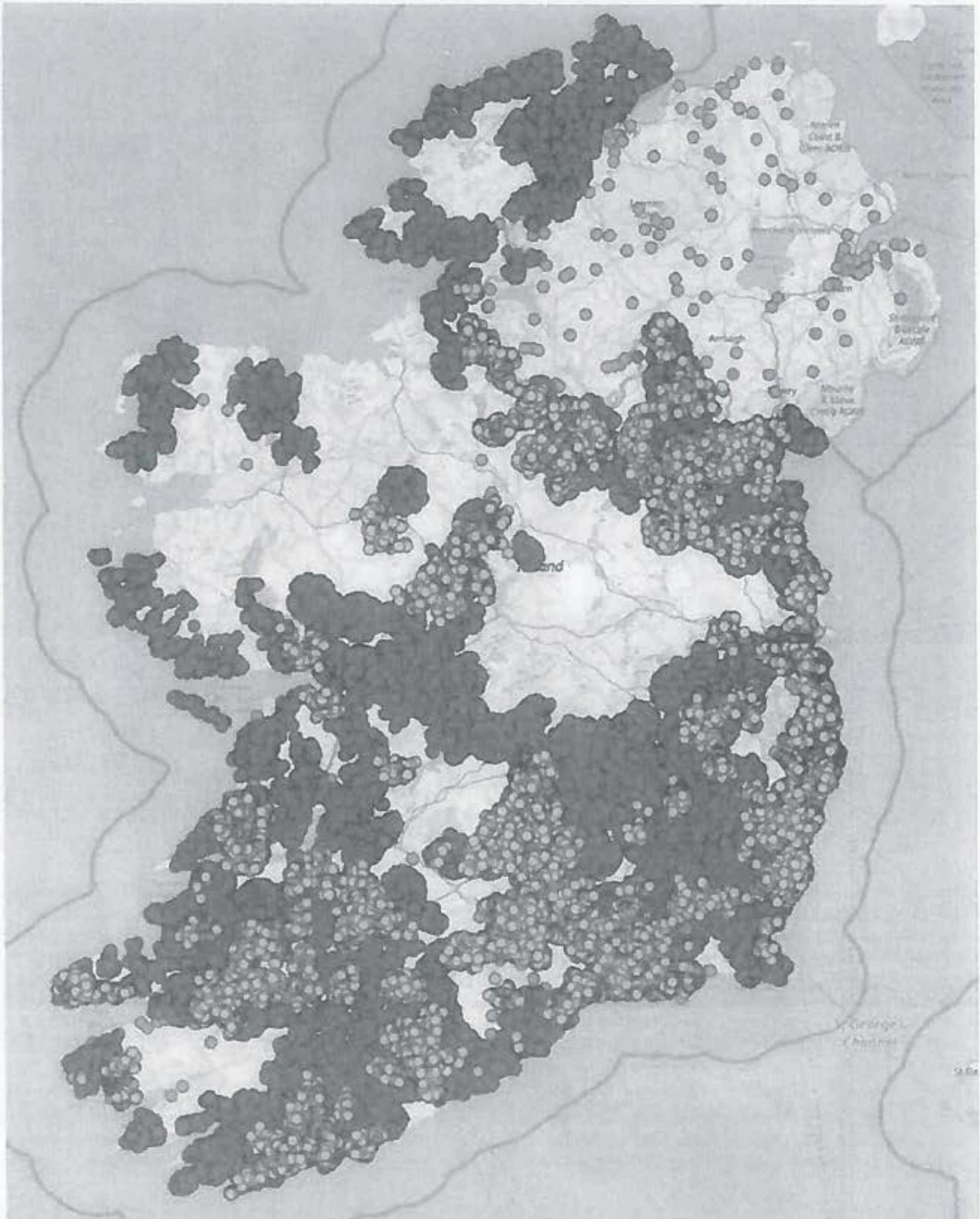



*Figure7.NGA and Planned NGA Premises Passed*

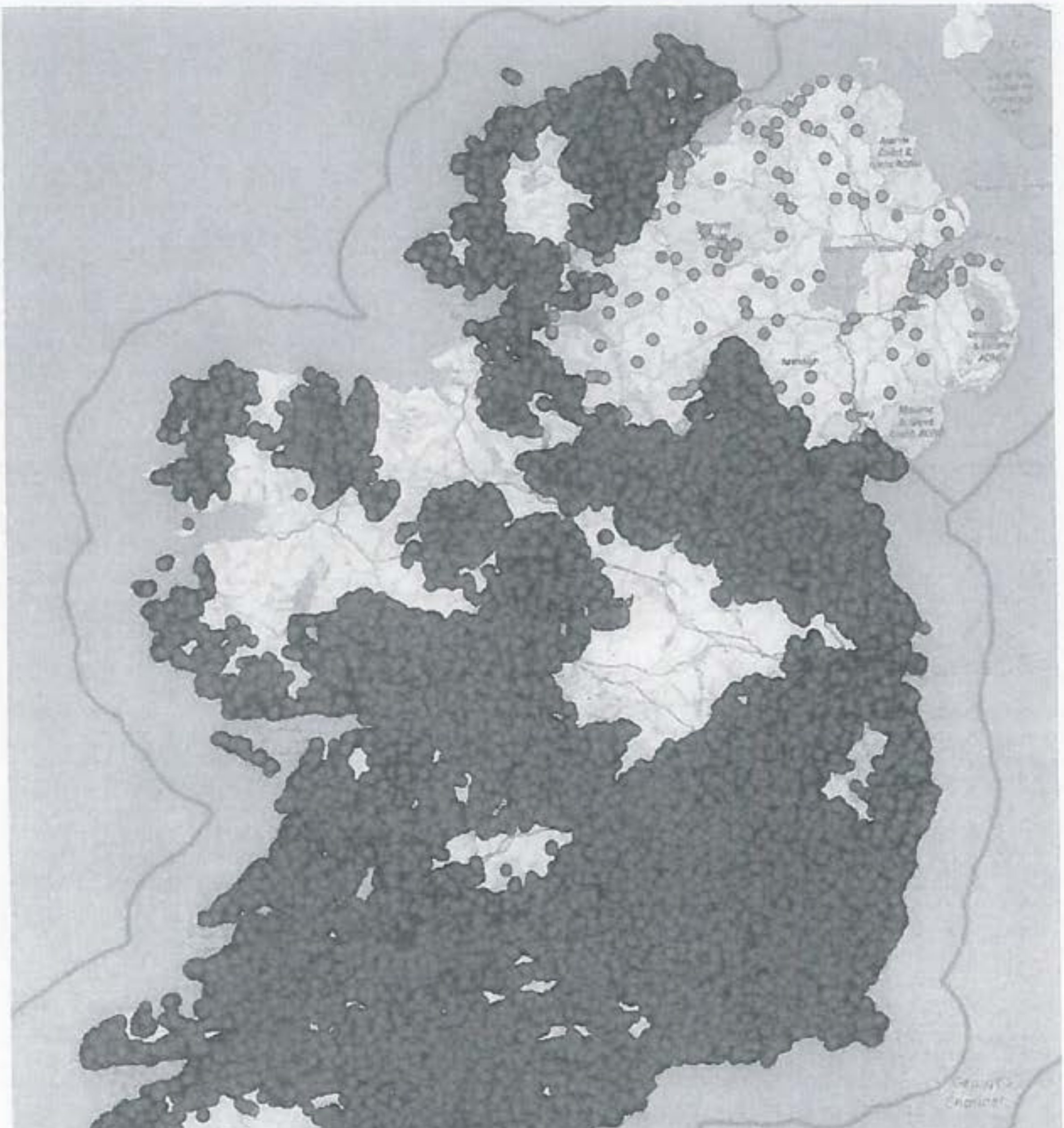


*Figure 8. NGA and Standard Premises Passed*

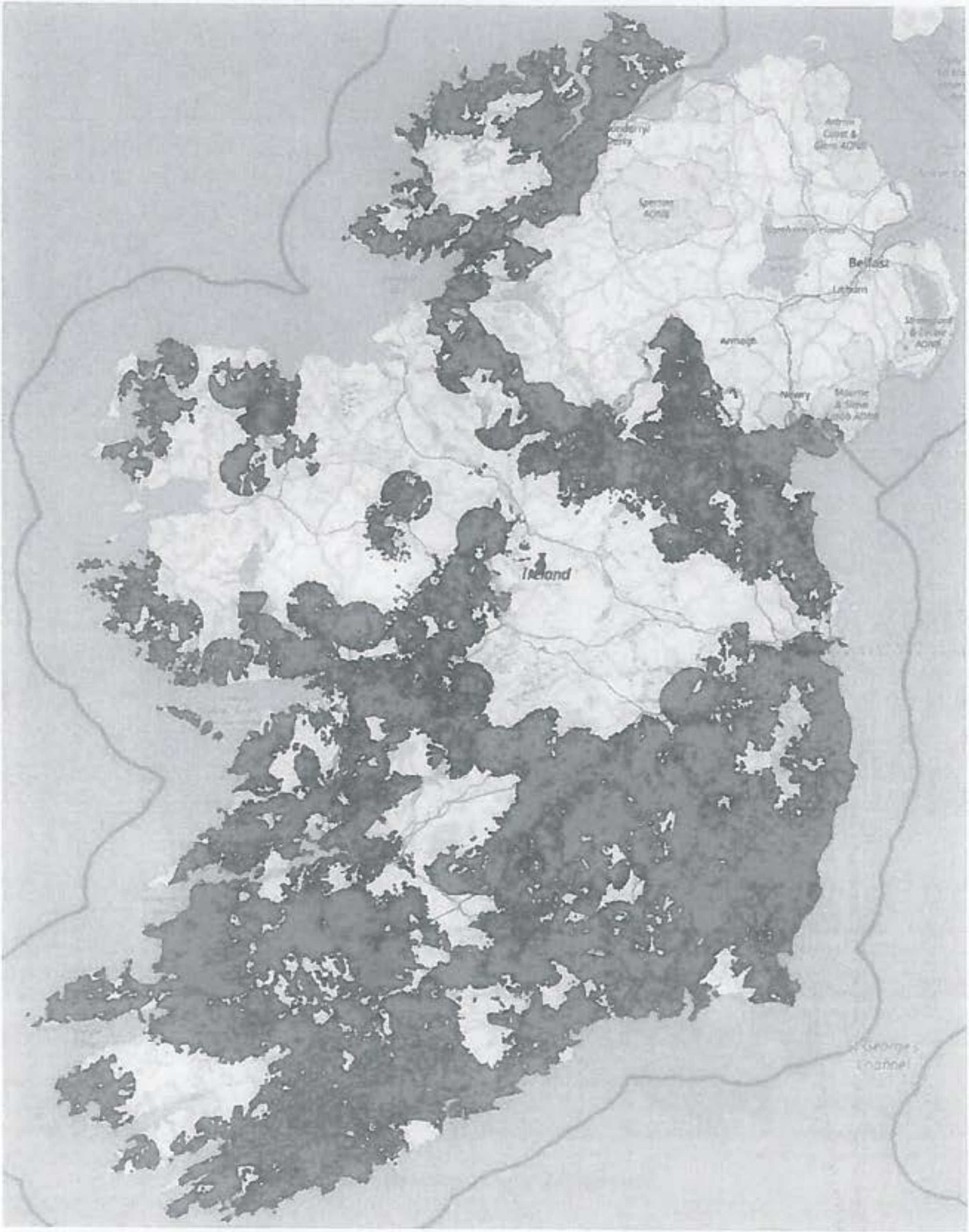



*Figure 9. NGA and Standard Premises Passed Coverage Area*

# APPENDIX D – EIRCODE DATA

We have created the following data sets as electronic supplement to this document: -

| File | Type | Description |
|---|---|---|
| All-Operators-NGA | ESRI Shapefile and KML File | This Shapefile includes the EirCodes with Line of Sight to all participating operators and has link distances and AP site locations embedded. |
| All-Operators-NGA-Planned-Only | ERSI Shapefile and KML File | This Shapefile includes the EirCodes with Line of Sight to all planned NGA-capable AP Sites for all participating operators including link distances. |
| All-Operators-NGA-EirCode-Details | CSV | This file is a list of the EirCodes with location of an associated operator with Line of Sight for NGA coverage. |
| NGA-Coverage-EirCodes | CSV | This is a list of EirCodes that have NGA coverage from one or more participating operators. |
| Non-NGA-Coverage-EirCodes | CSV | This is a list of EirCodes that have NGA or non-NGA coverage from one or more participating operators. |
| All-Operators-NGA-Planned-Only-EirCodes | CSV | List of EirCodes from all participating operators that have planned Line of Sight coverage at NGA spec. |
| EirCodes_Multi_NGA | CSV | List of EirCodes with Line of Sight NGA coverage from two or more participating operators. This also shows a count of the coinciding operators per EirCode. |
| EirCodes_Multi_NGA-with_location | CSV | List of EirCodes as well as locations with Line of Sight NGA coverage from two or more participating operators. This also shows a count of the coinciding operators per EirCode. |
| All-Operator-NGA-Coverage-Area | GeoTIFF and ESRI Shapefile | Coverage area of all participating operators as a composite viewshed for NGA capable sites. This includes a single contour for NGA coverage of a minimum of 30 Mbps download speed. |

This data is available HERE

# APPENDIX E – WISDM™ LINE OF SIGHT ENGINE

## HIGHLIGHTS

Wireless coverage WISDM comprises of a family of ultra-high performance wireless planning systems developed by Boundless Networks Ltd.

WISDM WISP Edition is an interactive planning and design system built to facilitate the creation of scalable, robust and performant fixed wireless networks for Wireless IPSs. It enables the rapid creation of 'Ideal' wireless networks over very large areas of thousands of square kilometres. It is well suited to rural expanses as well as mixed and urban environments too. Once an Ideal network has been designed, the network can be fine-tuned to consider build constraints and resiliency in real time.

WISDM can also be used to analyse the coverage of an existing wireless network and perform 'what-if' tests to plan ad-hoc extensions to a network to verify potential coverage and backhaul.

Using WISDM, a predictable coverage model can be prepared in hours and **detailed coverage of individual properties** can be predicted with an extremely high level of accuracy. Site planning and acquisition is accelerated by use of the interactive planning tools, allowing rapid decisions about mast location to be made with instant coverage impact reporting.

## OVERVIEW

WISDM comprises of several components and processes to complete the overall solution. At the heart of the system is a very high performance wireless Line of Sight (LoS) calculation engine. The LoS engine can calculate over 150 million wireless line of sight tests per second and can use a wide variety of terrain and surface obstruction data sets at any resolution.

Overall, WISDM WISP Edition performs the following tasks: -

1. Site Finder. This creates an 'Ideal' list of sites where masts could be located for optimum coverage for a given number of target premises passed from a target premises dataset. Target premises can be a list of all properties from a comprehensive source, such as Ordnance Survey AddressBase, or a subset of premises in say, a Government Intervention area. Assumptions can be used to set mast profiles which would include mast height and effective wireless range. For example, the Site Finder can be run with parameters which state that 20 locations could be built with 30m towers, then calculate how many 15m towers would be needed to pass a certain quantity of target premises.
2. Backhaul Modelling. The Backhaul Modeller analyses a Site Location dataset and performs line of sight tests between them to create microwave backhaul. Assumptions can be used to help plan for the style of links to be used. For example, links up to 5km can be coloured differently than links from 5km to 17km. This helps when planning a network that has optimum resilience, performance and operating costs due to the potential costs incurred to run licensed microwave links or fibre backbone.
3. Wide Area Network (WAN) Visualizer. The WAN Visualizer provides full-screen mapping to allow users to see the overall shape of a network and the distribution of different sized towers and backhaul connections between sites. The WAN Visualizer can be called from the Site Coverage and Modelling system.
4. Site Coverage and Modelling System. This is an interactive web-based tool that allows planners to review the calculated Ideal Sites and move them on a map. At each point, the user can see instantly the impact of changes to coverage of Target Premises, as well as backhaul connections to other sites.

5. Backhaul Link Capacity Planning. Backhaul links can be described in terms of capacity and latency. Client connection volumes can also be applied to sites and WISDM will predict traffic load and volumes relative to transit or fibre injection points.

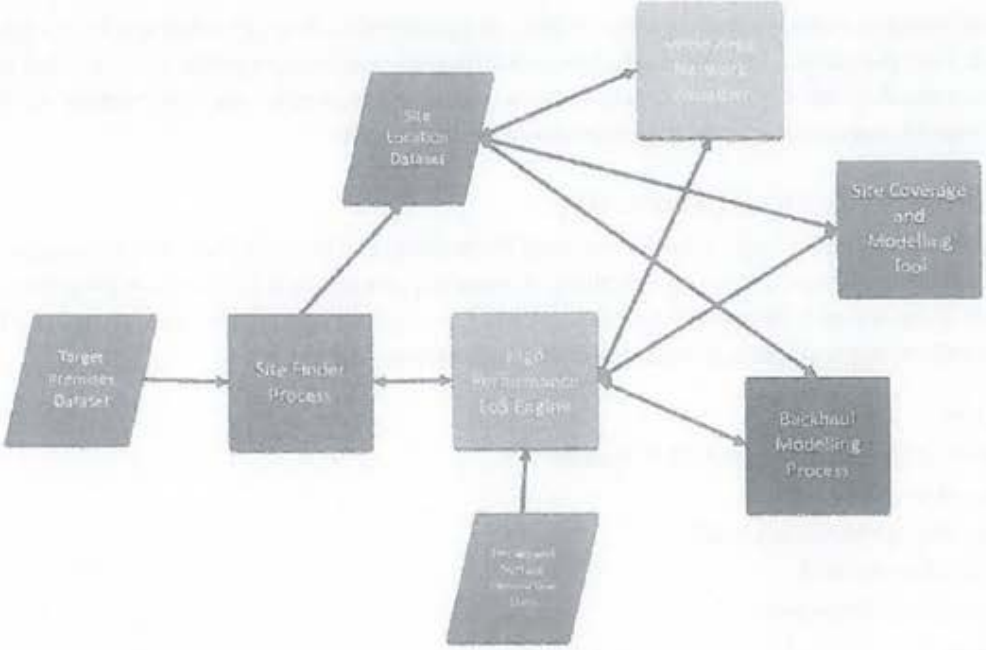



*Figure 9. WISDM System Schematic*

## LoS Engine

The WISDM LoS Engine is a custom-built high performance wireless propagation calculator developed in Native C and CUDA. It is a multi-threaded application, currently running on a server farm at Wireless Coverage and is accessed via a C API. This currently operates with 5,000 GPU cores to achieve around 500 million line of sight transactions per second when creating viewsheds but can be scaled further as required.

The LoS Engine has forward and reverse lookup features that are optimised to illustrate coverage from a single point, or supply from multiple points. These features are so fast that they can be operated in real time and take into consideration precision line of sight calculations as well as frequency, loss (according to ITU recommendations) and 3d antenna patterns for both transmitter and receiver.

## Line of Sight Engine Technical Overview

Specific variants of the Line of Sight Engine exist for Forward (Viewshed) and Reverse (Best AP) coverage over large areas at any sample resolution. Below is an example of point to point request, but this is replicated over larger areas for the Forward and Reverse viewshed methods, where a map grid is also specified. The application uses the following parameters as input to each request via an API: -

- Site A Lat/Lon
- Site A transmitter height above ground in metres
- Site A transmitter power dBm
- Site A transmitter antenna gain in dBi
- Transmit frequency in MHz
- Scanning resolution in metres
- Site B Lat/Lon
- Site B receiver height above ground in metres
- Site B receiver antenna gain in dBi
- Percentage of first Fresnel required for partial line of sight in %
- Percentage of first Fresnel required for no line of sight in %
- Antenna Model (used for beam pattern)

The response for each request includes the following: -

- Link distance in metres
- Pass Status (Full Line of Sight, Partial Line of Sight or No Line of Sight)
- Predicted Receive Signal Strength (RSL) in dBm, assuming full Line of Sight
- Azimuth from Site A in degrees from true North
- Azimuth from Site B in degrees from true North
- Elevation from Site A in degrees
- Elevation from Site B in degrees
- Antenna Model (used for beam pattern)
- Optional link ground profile .PNG image file, illustrating the link profile and first Fresnel shape

Point A name: Point A
Point B name: Point B
Coordinates of A: 53.673302°, -2.664143°
Coordinates of B: 53.645783°, -2.573456°
Height of A: 20 m
Height of B: 10 m
Power: 20 dBm
Antenna gain of A: 13 dBi
Antenna gain of B: 23 dBi
RF frequency: 5825 MHz

Estimated RSSi: **-69.37 dBm**
Azimuth from A: **117.05°**
Azimuth from B: **297.05°**
Elevation from A: **1.38°**
Elevation from B: **-1.38°**
Link distance: **6734.22 m**

**FIGURE 1 SAMPLE LOS ENGINE INPUT AND OUTPUT**

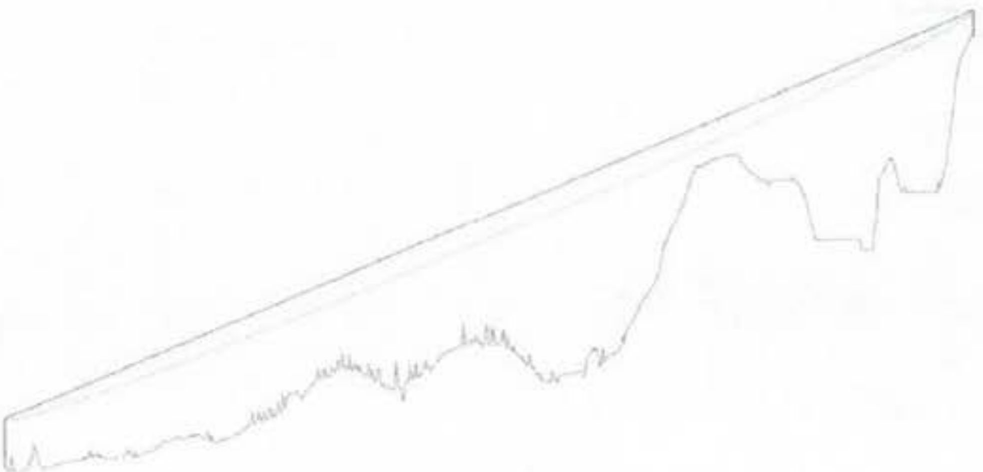


*Figure 10. Eexample Ground LOS Path profile showing Los and Fresnel zone*

## MATHEMATICAL AND TECHNICAL LOS MODEL

A DSM elevation raster (of chosen resolution) of the target area is loaded into memory (~11GB GeoTIFF file equates to around 6,500 sq miles, imported with GDAL C library) into a flat array of 32-bit floats in a geodetic WGS84 latitude / longitude grid. This stays loaded in memory for every call of the function. A function exists to return the height in metres above sea level for any given latitude + longitude using bilinear interpolation in the grid. This allows for very fast indexed surface elevation lookups for any point in target area with high resolution.

64-bit integers are used for indexing coordinates and x87 80-bit floating-point numbers are used in coordinate calculations.

2 functions exist, geodetic_to_ecef and ecef_to_geodetic for converting between ellipsoidal WGS84 coordinates and cartesian ECEF coordinates.

geodetic_to_ecef is an implementation of Section 10.2.1 from B. Hofmann-Wellenhof, H. Lichtenegger, J. Collins' GPS - theory and practice as follows:

$$N(\phi) = \frac{a^2}{\sqrt{a^2 \cos^2 \phi + b^2 \sin^2 \phi}}$$
$$X = (N(\phi) + h) \cos \phi \cos \lambda$$
$$Y = (N(\phi) + h) \cos \phi \sin \lambda$$
$$Z = \left( \frac{b^2}{a^2} N(\phi) + h \right) \sin \phi$$

where $h$ is height in metres; $\phi$ is latitude; $\lambda$ is longitude; $a$ is the Earth's equatorial radius in metres; $b$ is the Earth's polar radius in metres; *(X,Y,Z)* is the cartesian ECEF coordinate.

ecef_to_geodetic is an implementation of J. Zhu's "Exact conversion of earth-centred, earth-fixed coordinates to geodetic coordinates" formula as follows:

$$r = \sqrt{X^2 + Y^2}$$
$$E^2 = a^2 - b^2$$
$$F = 54 b^2 Z^2$$
$$G = r^2 + (1 - e^2) Z^2 - e^2 E^2$$
$$C = \frac{e^4 F r^2}{G^3}$$
$$S = \sqrt[3]{1 + C + \sqrt{C^2 + 2C}}$$
$$P = \frac{F}{3\left(S + \frac{1}{S} + 1\right)^2 G^2}$$
$$Q = \sqrt{1 + 2e^4 P}$$
$$r_0 = \frac{-(P e^2 r)}{1 + Q} + \sqrt{\frac{1}{2} a^2 (1 + 1/Q) - \frac{P(1 - e^2) Z^2}{Q(1 + Q)} - \frac{1}{2} P r^2}$$
$$U = \sqrt{(r - e^2 r_0)^2 + Z^2}$$
$$V = \sqrt{(r - e^2 r_0)^2 + (1 - e^2) Z^2}$$
$$Z_0 = \frac{b^2 Z}{a V}$$
$$h = U \left( 1 - \frac{b^2}{a V} \right)$$
$$\phi = \arctan \left( \frac{Z + e'^2 Z_0}{r} \right)$$
$$\lambda = \operatorname{arctan2}(Y, X)$$

where *(X,Y,Z)* is the cartesian ECEF coordinate; $h$ is height in metres; $\phi$ is latitude; $\lambda$ is longitude; $a$ is the Earth's equatorial radius in metres; $b$ is the Earth's polar radius in metres; $e$ is the Earth's first orbital eccentricity; $e'$ is the Earth's second orbital eccentricity.

The 3D cartesian coordinates of each radio is found by sampling the ground elevation of the two points and adding on the mast heights, and then using geodetic_to_ecef. The accurate straight-line distance between the two radios can be found by using $\sqrt{dx^2 + dy^2 + dz^2}$

The straight line between each *(x,y,z)* position is divided into linear interval points at the desired scan resolution. These points are then converted back into (latitude, longitude, height) WGS84 coordinates using ecef_to_geodetic.

The surface elevation at each of these WGS84 points is sampled and the resulting coordinates + height are converted back into ECEF coordinates.

The resulting 3D ECEF coordinates should mostly be in a flat plane and represent the elevation profile of the terrain under the line between the two radios, including the curvature of the Earth. These coordinates are transformed into flat 2D coordinates by rotating them through 3 axes using transformation matrices. Once they are rotated to a flat plane against the axes, the resulting *Z* coordinate will be approximately zero and is discarded to produce 2D coordinates.

A 2D straight line is plotted between the two radio coordinates and perpendicular to this line, points are calculated and plotted for the first Fresnel zone and given threshold percentages within the Fresnel zone. The radius *r* in metres of the first fresnel zone is calculated using:

$$r = \sqrt{\frac{cd(t-d)}{1000000ft}}$$

where *c* is the speed of light in $ms^{-1}$; *d* is the distance along the line in metres; *t* is the total distance between the two radios; *f* is the frequency in megahertz.

Intersection with the surface profile polygon and the plotted Fresnel threshold points is tested using binary search + linear interpolation.

The basic RSL *s* in decibels is calculated using:

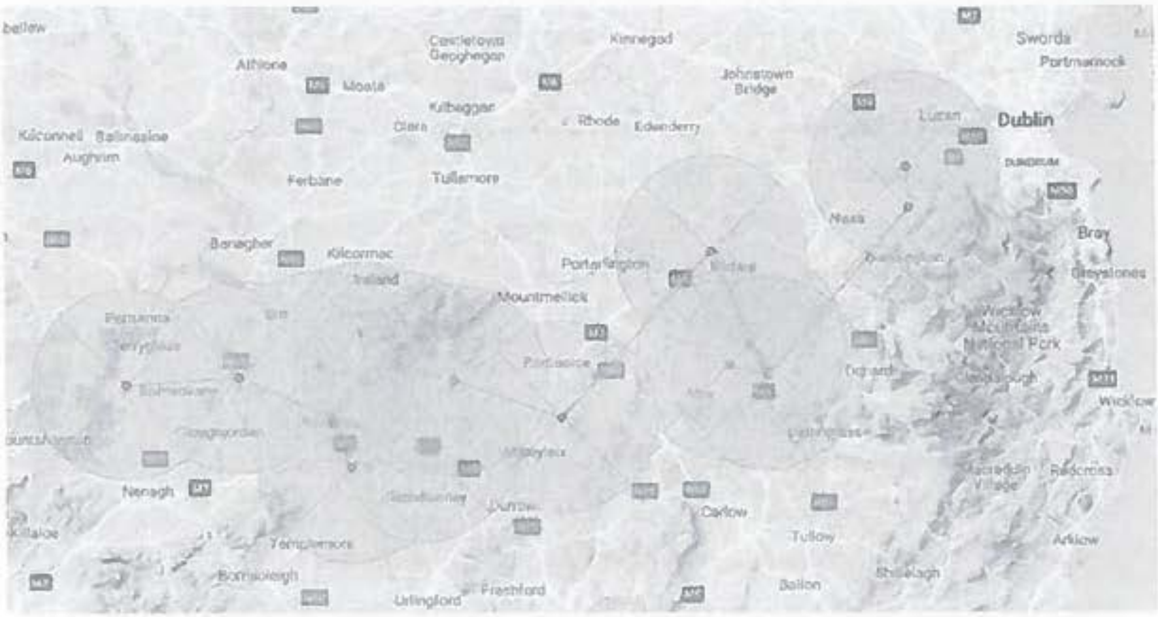
$$l = 92.5 + 20\log_{10}\left(\frac{d}{1000}\right) + 20\log_{10}\left(\frac{f}{1000}\right)$$
$$s = p + g_1 + g_2 - l - t$$

where *l* is the free-space path loss in decibels; *d* is the distance in metres; *f* is the frequency in megahertz; *p* is the power of the transmitter; *g1* and *g2* are the antenna gains of each antenna; *t* is the transmission line loss, assumed to be 1 decibel. Further ITU-R attenuation models are applied for appropriate bands, but not described in this document.

Wireless Connect Ltd.

Response

# Submission on 2019 DCCAE NBP Intervention Mapping Data exercise



Contents

**Preliminary**

We regret that due to the very short space of time allowed by the Department for this Consultation and due to the very large and time-consuming amount of data required to fully comply with its requirements we have been unable to address the totality required. We and other SME FWA ISPs have written to the Department in September explaining the problems that this short time-scale holiday-centred consultation has caused and seeking an extension of time. It is most regrettable that the Department did not grant sufficient notice or sufficient extensions to the consultation period.

We have invested enormous time and effort with short notice and in the peak holiday period, engaging with the following stakeholders who also have been dealing with staff on leave;

- We along with 27 other Regional ISPs have been compiling a list of our sites, engaging GIS & Radio coverage consultants at wirelesscoverage.com
- WirelessCoverage.com used the best available 2.5m resolution LIDAR and Digital Surface Model Data analyse LOS from our sites to the centroid of every Eircode premises in the country.
- Multiple Wired Network Hardware technology providers to get their datasheets, roadmaps and plans for the next 7 years.
- Multiple active Radio Hardware technology providers to get their datasheets, roadmaps and plans for the next 7 years.
- Multiple Antenna Hardware manufacturers to get their datasheets, roadmaps and plans for the next 7 years.
- Multiple Software technology providers to get their roadmaps and plans for the next 7 years.
- International Internet IP Transit Providers to get information about future capacities at our Points of handover.
- Multiple local backhaul providers about future capacities at our Points of handover
- Multiple national backhaul providers about future capacities at our Points of handover
- We with the help of other local ISPs have been compiling a list of our sites, engaging a GIS & Radio coverage consultants at wirelesscoverage.com to process all our sites with a view of getting a list of all premises covered by our existing infrastructure to show what premises and areas we cover.

# A1 Technical Information

## 1 Introduction

We have built our network around having good bandwidth with consistent and low latency, so as to support all converged IP services. We support many businesses and homes with Voice over IP VoIP telephony services. Infact our clients have a wider choice of telephony offerings with Voice over IP which helps our customers access other services and reduce cost All of which is great our customers.

The advances in wireless broadband technology in the past 15 years has been very considerable and particularly significant in the last 4-5 years. In that time, by our company keeping up with the latest in wireless technology we have been able to deliver the benefits of reliable high-speed broadband to Rural Ireland and, as a result, there is a wide variety of converged services available to our customers. In fact, more than half of our customer internet traffic is now video based, such as streaming video content from:

- RTE
- BBC iPlayer
- Apple TV
- YouTube
- Netflix
- High Resolution CCTV for our customers peace of mind and security and indeed farmers for monitoring their animals' welfare

In addition to this we support many businesses / homes with Voice over IP VoIP telephony services.

A number of our regional ISP colleagues have deployed their own IPTV distribution platforms for their ISP Customers, these operators include:

- Airwire Ltd.
- Real Broadband Ltd.
- Kerry Broadband Ltd.

They are very pleased with the results and we are actively considering collaborating with them and other operators to bring IPTV over our own high-quality high-speed broadband network.

We also support business users with remote working solutions through VPNs, Remote Desktop Environment and cloud-based productivity suites. Our customers report excellent results with video conferencing which allows for more remote working less commuting, less traffic congestion, reduced carbon footprint and a greater quality of life for our customers in Rural Ireland. We are delighted that our customers reap the benefits of high-speed broadband in Rural Ireland today, benefits, we might add that exist at no cost to the taxpayer.

## 1.1Description of network Architecture

Our Network is currently an IPv4 Network that is IPv6 ready with our equipment and our upstream all supporting IPv6. IPv6 is in the process of being rolled out on our network. Our network is predominantly developed on top of Ethernet Based Network devices. We have a Resilient network in terms of the following

- Transit ISP resilience (via 2x Transit Providers via 2x redundant BGP routers
- IXP Internet Exchange Point Resilience via 2x Separate switches and BGP routers)
- Backhaul Provider Resilience we have 2x Separate Backhaul providers
- We have multiple links with each backhaul provider to diverse sites.
- We have redundancy on links between sites.
- Our Core network in our Datacentre has fully redundant power A&B
- And all devices in the Datacentre including Virtualisation infrastructure supporting services such as DNS, NTP and SMTP have full Hardware redundancy.

Our network internally is a Routed Layer 3 network with failover provided with OSPF.

Our client traffic and traffic for other ISPS provided through a minimum of 2x Layer2 Tunnels overlaid on our Layer 3 resilient Network.

Our Base stations all have resilient backhaul into an access concentrator which terminates the 2 layer 2 tunnels and bridges them onto a vlan on a poe switch to distribute Internet connectivity to Powered Sectors. The Powered sectors are each on Layer 2 Isolated ports. We take standard precautions to prevent abuse of our network on Layer2 and Layer 3.

The link between the Subscriber / CPE is non redundant (as is standard for internet access last hop).

Each subscriber unit has:

- non internet management vlan to facilitate diagnostics and monitoring.
- internet vlan which carries the customer traffic across our network on to the internet
- a unique public IPv4 address delivered via DHCP that is not natted or translated.

We implement BCP38 and MANRS on our network to improve security. We have other Security strategies for dealing with Security / network abuse such as spoofing and DDoS attacks.

[Insufficient Time to Complete this section with the time constraints imposed by DCCAE]

## 1.2.Access network technology

We operate a Fixed Wireless Access (FWA) Network in the ISM 5GHz & License Exempt 5.8GHz bands. We use Ethernet based data link layer technology. For our NGA Access Deployment we have chosen Cambium sectors and client units.

On our Base station sites, we have deployed Sectors with the technical specifications as outlined in the following section. They have already been deployed following the deployment strategy which allows for self-funded organic growth and infill as the site matures and consumers become aware of the improved new service offering available to them.

On a given site that has 360 Degrees field of view (on top of a hill / mountain) we have deployed 4x 90-degree Cambium advanced sector antennas to provide coverage in the area. On a Base station site that has less of a field of view, in that case we have deployed the requisite number of 90-degree Cambium advanced sector antennas to cover that area. Additional capacity has been added by

- using additional sectors in the form of tightly focused sector antennas to maintain NGA levels of speeds that the customers are accustomed to. The tightly focused sector antennas serve to minimise external noise and facilitate frequency reuse.
- Using additional beamforming advanced sector antennas.

The additional capacity is added on an ongoing basis to maintain the performance in line with User expectations to ensure NGA Performance during the Busy Hour.

## 1.2.1 Access network technology and the Specification of the access equipment

We operate in the ISM 5GHz & License Exempt 5.8GHz bands. We use Ethernet based data link layer technology. For our NGA Access Deployment we have chosen Cambium sectors and client units. The Cambium sectors are powered using Power over Ethernet PoE switches from Ubnt or Netonix. And MikroTik RouterOS Routers are used to forward customer Internet traffic inside Layer 2 Tunnel Overlay on a Redundant layer 3 Routed network. With each customer getting a unique public IP without it being interfered with by Network Address Translation.

### 1.2.1 Base station Technology Deployed

In our Base stations we deploy the equipment described below to support the delivery of quality reliable internet to the customer.

A schedule of Routers used at each base station would be one or more of the following (depending on the site size: A schedule of Routers used at each base station would be one or more of the following (depending on the site size:

- Mikrotik RB1100AHx4 Router with a capacity for Routing up to 4Gb/s
  - https://i.mt.lv/cdn/rb_files/RB1100Dx4-171013102032.pdf
- Mikrotik Cloud Core CCR1016-12G Router
  - https://i.mt.lv/cdn/rb_files/ccr1016-12G-190612120511.pdf
- Mikrotik Cloud Core CCR1016-12G Router for routing up to 4Gb/s
  - https://i.mt.lv/cdn/rb_files/ccr1016-12G-190612120511.pdf
- Mikrotik RB4011iGS Router for capacity for routing up to 4Gb/s
  - https://i.mt.lv/cdn/rb_files/RB4011-RM-180919132428.pdf

A Schedule of PoE Switches on base stations are outlined below.

- UBNT EdgeSwitch ES-24-250W
    - https://www.ui.com/downloads/datasheets/edgemax/EdgeSwitch_DS.pdf
- UBNT EdgeSwitch ES-24-500W
    - https://www.ui.com/downloads/datasheets/edgemax/EdgeSwitch_DS.pdf
- Netonix WS-26-400-IDC
    - https://www.netonix.com/wisp-switch/ws-26-400-idc.html

### 1.2.2 Sector Technology Deployed

We deploy sectoral transmitters according to the design and strategy outlined earlier. We utilise Cambium Sectors with beamforming & GPS synchronisation to actively mitigate against Interference. The GPS Sync allows all sectors at a given base station site to transmit simultaneously and receive simultaneously, thereby eliminating self-interference & co-located interference. When GPS sync is combined with Advanced Antenna Designs it allows an operator to reuse frequencies to increase capacity at a site. The Upload download ratio on the access network is fixed at 25% Up, 75% down. This allows for even better ratio than what is required for NGA. There are other active technologies deployed in the electronics to mitigate against interference through the use of:

- Integrated Static RF filters
- Integrated Dynamic tuneable RF filters
- Advanced digital signal processors
- Forward error correction FEC mechanisms
- Adaptive Coding Modulation (ACM)
- Transmit Power Control (TPC)
- Subscriber isolation

A schedule of the sector equipment used is outlined below:

- GPS Synchronised dynamic filtering EPMP 3000 4x4 MUMIMO with 90deg Sectors with smart beamforming antenna.
    - https://cdn.cambiumnetworks.com/wp-content/uploads/2018/10/SS_ePMP_3000_10032018-1.pdf
    - https://cdn.cambiumnetworks.com/wp-content/uploads/2018/10/SS_ePMP3000_SectorAntenna_10032018_bleed.pdf
- GPS Synchronised dynamic filtering EPMP2000 2x2 MIMO with 90deg Sectors with smart beamforming antenna.
    - https://cdn.cambiumnetworks.com/wp-content/uploads/2018/08/SS_ePMP_2000_06222018.pdf
    - https://cdn.cambiumnetworks.com/wp-content/uploads/2017/10/SS-ePMP-Sector-antenna-04062016v1.pdf
- Smart Beamforming Antenna that is used in the EPMP 2000 and EPMP3000
    - https://cdn.cambiumnetworks.com/wp-content/uploads/2017/09/SS_ePMP_SmartAntenna01032017.pdf
- GPS Synchronised EPMP 3000L 2X2 MIMO with 30deg, 40deg, 50deg, 60deg, 90deg scalar horn antennas.
    - https://www.cambiumnetworks.com/products/epmp/epmp-3000l-access-point/

- RF Elements 30 Degree Scalar Horn Sector Antenna HG3-CC-S30
  - https://rfelements.com/assets/Uploads/HG3-CC-S30-Datasheet3.pdf
- RF Elements 40 Degree Scalar Horn Sector Antenna HG3-CC-S40
  - https://rfelements.com/assets/Uploads/HG3-CC-S40-Datasheet3.pdf
- RF Elements 50 Degree Scalar Horn Sector Antenna HG3-CC-S50
  - https://rfelements.com/assets/Uploads/HG3-CC-S50-Datasheet2.pdf
- RF Elements 60 Degree Scalar Horn Sector Antenna HG3-CC-S60
  - https://rfelements.com/assets/Uploads/HG3-CC-S60-Datasheet2.pdf
- RF Elements 30 Degree Asymmetrical Scalar Horn antenna HG3-TP-A20-30
  - https://rfelements.com/assets/Uploads/Datasheet-HG3-TP-A20-30.pdf
- RF Elements 60 Degree Asymmetrical Scalar Horn antenna HG3-TP-A60
  - https://rfelements.com/assets/Uploads/Datasheet-HG3-TP-A60.pdf
- RF Elements 90 Degree Asymmetrical Scalar Horn antenna HG3-TP-A90
  - https://rfelements.com/assets/Uploads/Datasheet-HG3-TP-A90.pdf

### 1.2.3 Client Premises Equipment(CPE) Technology Deployed.

The Client units were chosen because they had the following features to maximise performance, minimise interference:

- Maximise spectral efficiency by utilising a minimum of 2 streams MIMO (on horizontal and Vertical Polarization)
- High Gain Focused Antennas
- Maximise client performance by ensuring adequate processor specification
- Adaptive Coding Modulation (ACM)
- Forward Error Correction (FEC)
- Transmit power Control (TPC)

We minimise interference by using high gain focused client antennas that have the effect of maximising the signal through accurate alignment (by a professionally trained installer) of the antenna's centre line with the base station. Utilising High gain Focused antennas has the following effects:

- Noise behind and beside the antenna minimised to a great extent.
- Minimises interference to other operators because the signal is focused on the base station (being a good neighbour)
- Minimises interference from other operators because the signal is focused on the base station (protection from noisy neighbours)
- Maximises signal to noise ratio (SNR)

A schedule of Client unit equipment deployed:

- Cambium Force 200 25dBi 5GHz Client units supporting throughputs of 80Mb/s down and 27Mb up on 20MHz
    - https://cdn.cambiumnetworks.com/wp-content/uploads/2017/10/SS_ePMP_Force200_06262018.pdf
- Cambium Force 300 25dBi 5Ghz supporting throughputs of up to 125mb/s down and 36mb/s up on 20MHz
    - https://cdn.cambiumnetworks.com/wp-content/uploads/2018/10/SS_ePMP_Force300-25_08212019.pdf
- Upgraded MikroTik LHG5 24.5 dBi Cambium ePMP elevate software installed on it.
    - https://i.mt.lv/cdn/rb_files/LHG-170927115805.pdf

## 1.3. Backhaul Network Technology and specification of Backhaul Technologies

**Our Backhaul is heavily dependent on Fibre. We use high Capacity FDD Links to transfer bandwidth from a fibre POH to a high site.**

### 1.3.1 Short Range Radio Backhaul Network Technology

**We make use of high frequency narrow beam links to bridge short gaps between fibre POHs and high sites. We make use of 17GHz / 24GHz / 60GHz License Exempt bands and Licenced bands for delivery of bandwidth from site to site or from Fibre POH to Site. We also deploy 5.8GHz GPS Synced Backup Backhaul to cover Extreme Weather Events that may affect Higher Frequency Links.**

- **We utilise 60GHz MikroTik 60GLHG for links less than 1.25km delivering 2Gb/s HDX which has 4 channels available for future expansion and redundancy.**
  - https://i.mt.lv/cdn/rb_files/LHGG-60ad-190611115231.pdf
- **Racom Ray3 17GHz 713Mb/s FDX FDD Radio Link up to 10km**
  - https://www.racom.eu/download/hw/ray/free/eng/00_letaky/ray-dsA4-en.pdf
- **Racom Ray2 17GHz 360Mb/s FDX FDD Radio Link up to 10km**
  - https://www.racom.eu/download/hw/ray/free/eng/00_letaky/ray-dsA4-en.pdf
- **SIAE ALFOplus 17/17GHz 500Mb/s FDD FDX Radio Link for Links up to 10km**
- **Racom Ray3 24GHz 1Gb/s FDX FDD Radio Link up to 6Km**
  - https://www.racom.eu/download/hw/ray/free/eng/00_letaky/ray-dsA4-en.pdf

**All of these equipment when deployed on a link allow for increased bandwidth for our customers, we monitor the usage on these deployed links and as soon as usage on any of these links are regularly and consistently over 75% we start a procurement process to upgrade the links, this is ensured that upgrades either soft or hard are implemented in time so as to keep our capacity always 20% above of Peak Demand. We monitor our usage using various SNMP graphing and Latency Testing Tools in our NMS system.**

### 1.3.2 Long Range Licensed Radio Backhaul Network Technology

In our network we have a number of Licensed links to bring data from a fibre enabled site to another site.

- Huawei Optix RTN905 2E with 2+0 XPIC 1Gb/s on 56MHz Channel Licensed Radio, 15GHz 18GHz
- Ceragon IP10 11GHz FDD Licensed Link with an unlimited capacity license 360mb/s FDX

All of these connections once installed allow for increased bandwidth for our customers, we monitor the usage and as soon as usage on any of these links are regularly and consistently over 75% we start a procurement process to upgrade the links, this is ensured that upgrades either soft or hard are implemented in time so as to keep our capacity always 20% above of Peak Demand. We monitor our usage using various SNMP graphing and Latency Testing Tools in our NMS system.

### 1.3.3 Wired / Fibre Backhaul Network Technology

For sites and POPS that have 10Gb/s + Capacity we utilise the following routers to forward traffic onto High sites via the Radio Point to Point links described earlier

- Arista 7050QS32
  - https://www.arista.com/assets/data/pdf/Datasheets/7050S_Datasheet.pdf
- Arista 7048T with SVIs with a forwarding capacity of 104Gb/s
  - https://www.arista.com/assets/data/pdf/Datasheets/7048T-A_DataSheet.pdf
- Mikrotik CCR running on an X86-64 Server Hypervisor with a forwarding capacity Defined by the NUMA & PCI-E architecture of the Virtualization Hardware 40Gb/s +
  - https://i.mt.lv/pdf/software_chr.pdf
- OpenBSD OpenBGPd Control plane X86-64 Server Hypervisor with a forwarding capacity Defined by the NUMA & PCI-E architecture of the Virtualization Hardware 40Gb/s +
  - https://OpenBSD.org

For sites with 10G+ we use the following switches

- Arista 7050 series Switches
  - https://www.arista.com/assets/data/pdf/Datasheets/7050S_Datasheet.pdf
- Arista 7048T with a forwarding capacity of 104Gb/s
  - https://www.arista.com/assets/data/pdf/Datasheets/7048T-A_DataSheet.pdf

For smaller POPs and for POPS with PoE demands we deploy the following schedule of equipment

- Mikrotik RB1100AHx4 Router with a capacity for Routing up to 4Gb/s
  - https://i.mt.lv/cdn/rb_files/RB1100Dx4-171013102032.pdf
- Mikrotik Cloud Core CCR1016-12G Router
  - https://i.mt.lv/cdn/rb_files/ccr1016-12G-190612120511.pdf
- Mikrotik RB4011iGS Router for capacity for routing up to 4Gb/s
  - https://i.mt.lv/cdn/rb_files/RB4011-RM-180919132428.pdf

A Schedule of PoE Switches on base stations are outlined below.

- UBNT EdgeSwitch ES-24-250W

    - https://www.ui.com/downloads/datasheets/edgemax/EdgeSwitch_DS.pdf
- UBNT EdgeSwitch ES-24-500W
    - https://www.ui.com/downloads/datasheets/edgemax/EdgeSwitch_DS.pdf
- Netonix WS-26-400-IDC
    - https://www.netonix.com/wisp-switch/ws-26-400-idc.html

## 1.3.2 Backhaul Network Technology (National, and Metro) and the specification of the Backhaul Providers

Our national Backhaul Providers include OpenEir and ESB Telecom.

### 1.3.2.1 OpenEir Backhaul

We have the following Services Contracted from OpenEir, with Masterplan and Masterplan Plus SLAs.

We have 2x 10Gb/s Ethernet WEIL Wholesale Ethernet Interconnect Links with OpenEir located in Dublin City.

We have checked the OpenEir Congestion Report and we have a clear upgrade path to the full 10G usage on the WSEAs and WEILs in our current Locations

We have 1x 10Gb/s Ethernet WSEA Wholesale Symmetric Ethernet Access installed and located in Roscrea Town

We have 4x 1G/s Ethernet WSEA Wholesale Symmetric Ethernet Access installed and located in;

- Templemore
- Roscrea
- South Dublin
- West Dublin

We have had a number of discussions with our OpenEir account manager and we note that Roscrea and Parkwest ,Portlaoise are on the NGN core network in OpenEir and do not have any current capacity issues and we don't fore see any issues with ordering multiples of 10G ports at these locations.

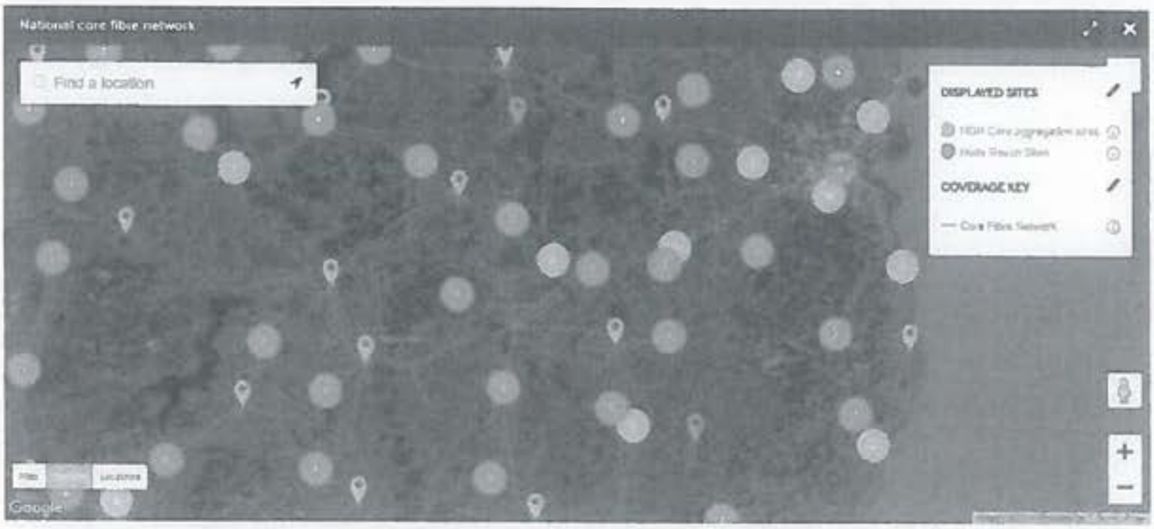



*Figure Showing OpenEirs, NGN Backhaul Network and key sites that we use/ intend to use for Backhaul supply of our network*

We intend to utilise Wholesale GEA (Gepon Ethernet Access) (from November 2019) for backup backhaul to High sites via OpenEir's GEPON network.

All of these connections allow for increased bandwidth for our customers, we monitor the usage and as soon as usage on any of these links are regularly and consistently over 75% we start a procurement process to upgrade the links, this is ensured that upgrades either soft or hard are implemented in time so as to keep our capacity always 20% above of Peak Demand. We monitor our usage using various SNMP graphing and Latency Testing Tools in our NMS system.

[Insufficient Time to Complete this section with the time constraints imposed by DCCAE]

### 1.3.2.2 ESB Telecom Backhaul

We have 1x 10G Interconnect with ESB Telecoms in Interxion DUB1

We have 1x 1G Ethernet Interconnect with ESB Telecoms in Interxion DUB1

We have 3x 750Mb/s Managed Licensed Links from an ESB Tower to our High sites located at:

- South West of Sliebhloom,
- Ballyroan
- Camross

We have a confirmed as an upgrade path to a 2 x 10G DWDM based Ring from our site giving us an upgrade capacity within 3months of 2x10G backhaul to our Dublin POP. In discussing with my account manager, we are assured that we can order multiples of that on different wavelengths for more capacity. The POH for the 2x 10G outlined located in Ballybrophy


*Figure showing ESBT fibre Ring around Ireland in Red and Blue, and Licensed Links to our Sites in Green.*

All of these connections allow for increased bandwidth for our customers, we monitor the usage and as soon as usage on any of these links are regularly and consistently over 75% we start a procurement process to upgrade the links, this is ensured that upgrades either soft or hard are implemented in time so as to keep our capacity always 20% above of Peak Demand. We monitor our usage using various SNMP graphing and Latency Testing Tools in our NMS system.

[Insufficient Time to Complete this section with the Time constraints imposed by Department]

### 1.3.3 External Edge Capacity

Wireless Connect own and operate AS62129 (formerly AS198988)

We have an External Edge capacity of 40G GB/s which is interconnected via Dual redundant eBGP edge routers running OpenBSD and OpenBGPD as the control plane and Dual Arista 7050QX32 as the Forwarding Routers. Layer 2 forwarding is provided by Dual Redundant Arista 7050QX32 switches running in a MCLAG (multi chassis Lag configuration).

We have 1x 10G IP Transit from Cogent AS174

We have 1x 10G IP Transit from GTTAS5580

We have 1x 10G interconnect with INEX LAN1 for peering with other Independent and self-financed nonsubsidised Irish ISPS, Irish ISPs, International ISPs and large content providers.

We have 1x 10G interconnect with INEX LAN2 for peering with Independent and self-Financed nonsubsidised Irish ISPS, Irish ISPs, International ISPs and large content providers.

All of these connections allow for increased bandwidth for our customers, we monitor the usage and as soon as usage on any of these links are regularly and consistently over 75% we start a procurement process to upgrade the links, this is ensured that upgrades either soft or hard are implemented in time so as to keep our capacity always 20% above of Peak Demand. We monitor our usage using various SNMP graphing and Latency Testing Tools in our NMS system.

## 1.4. Design for the national backhaul network including any traffic and capacity assumptions

The Backhaul network we have built has been designed around using quality backhaul from providers with an SLA that is appropriate for what are considered arterial paths for our network.

We use 8 Links spread across 2 Backhaul providers from our Main POP in Dublin to provincial towns around our network. From these provincial towns we utilise our own infrastructure built with high capacity ethernet radio links to get the bandwidth up to the nearest high site. We design the Radio links with adequate fade margins to achieve a minimum of 99.95% availability.

We introduce redundant paths between high sites using radio links so that if there is a fibre break in one provincial town, we can fail over via a number of radio links to a fibre link in another provincial town. We also supplement our primary high speed backhaul connections with backup connections over gepon fibre connections as a backup of last resort.

[Insufficient Time to Complete this section with the Time constraints imposed by Department]

## 1.5. The Specification of all types of Customer Premises Equipment which the operator (i) is using (ii) plans to use (if not already NGA).

**Please see section 1.2.3 for more information on our NGA Compliant CPEs.**

## 1.6. Coverage Data set

We put a lot of effort into collaborating with David Burns and his colleagues at WirelessCoverage.com in the UK.

### 1.6.1 Table of Location of Base stations

We have 43 base stations, throughout the following counties:

- North Co. Tipperary
- Co. Offaly
- Co. Laois
- Co Kildare
- West Co. Dublin

Redacted

[insufficient time to complete this due to time constraints and lack of notice]

### 1.6.1a Location of Base stations as illustrated in a MAP

The list of Base Stations that were used in wirelesscoverage.com WISDM LIDAR Line of Sight analysis software.

Redacted

[insufficient time to complete this due to time constraints and lack of notice]

### 1.6.2 Table of Location of Connected Clients

List of Connected customers in the form of EIRCODEs, Please note that this only includes Customers who we have Eircodes for as we are operating longer than the Eircode System

Redacted

[insufficient time to complete this due to time constraints and lack of notice]

### 1.6.3 Table of Location of Covered Premises Physically Tested on Site

List of sites where we have been on site to conduct Line of Sight surveys and have confirmed LOS

Redacted

[insufficient time to complete this due to time constraints and lack of notice]

### 1.6.4 Table of Location of Premises Passed based on High Resolution LIDAR and DSM data

We got wirelesscoverage.com to carry out a LOS survey based on the base station data we supplied them. The data shows that with the extensive hard work and investment already made by our company we have passed over **28,940** Premises in Ireland. A lot done more to do.

Redacted

[insufficient time to complete this due to time constraints and lack of notice]

### 1.6.5 LIDAR LOS testing and Methodology

We have engaged WirelessCoverage.com to build a Digital surface model based on high quality LIDAR / DSM data. We have supplied Wirelesscoverage.com a list of Sites and height of sectors to produce a list of premises that would be covered with clear line of sight

## Approach according to WirelessCoverage.com

The approach used for this project was designed to be as comprehensive and detailed as possible, using the best quality data and modelling tools available.

Detailed data was prepared to perform this analysis comprising of: -

- The latest EIRCODE dataset, purchased in August 2019
- A Digital Surface Model (DSM) for the whole country from Bluesky International, who have the most contemporary dataset currently available. They hold data at 1m resolution, which was scaled to 2.5m resolution using a bilinear interpolation method. Where any gaps in their coverage were identified SRTM data was used and interpolated to avoid any hard edges in the height data. More information on the data is available below
- Mast Site Data from our ISP
- WISDM Wireless Modelling system, which performs detailed line of sight tests between all properties and all tower sites. Further details on the WISDM Line of Sight Engine are included Below

### Method according to WirelessCoverage.com

Data from our ISP was collected in August and September 2019 and imported into WISDM. Sites were classified as Standard or NGA and we also gathered details on future planned sites. The distinction between Standard and NGA sites is based upon the quality and style of equipment currently installed at these sites, along with the backhaul feeds. Those classified as NGA are capable of connecting premises at NGA speeds of 30Mbps download and 6Mbps upload (as defined by DCCAE Assessment Criteria.

Using WISDM, wirelesscoverage.com ran several coverage passes to all EIRCODE centroids: -

1. All Sites from our ISP at NGA
2. All Sites from our ISP at non-NGA

Within each pass, WISDM takes each Site within the test and performs a Wireless Line of Sight test to each property within a given radius. It is important to note that a Wireless Line of Sight Test differs from an optical test, as it takes into account the Fresnel 1 Zone around the direct (optical) path. This is a more robust means of determining line of sight. In this exercise, we discounted all properties that had more than 15% Fresnel 1 incursion, and therefore does not include properties with Near Line of Sight, which in many cases could successfully be connected.

Where a property does have Wireless Line of Sight, it is excluded from further tests within that pass, in order to avoid double-counting properties.

We then performed analysis of the coverage list from each operator with NGA coverage to identify those properties that could receive NGA service from more than one operator.

## NGA Assumptions

Due the variety of equipment mounted at each site, we have taken a cautious approach to whether a site is capable of delivering NGA speeds. As such, we have taken a worst-case assumption of the type of equipment used for access points or base stations.

We considered the signal level that would be required to get the full modulation rates on the most basic of commonly installed fixed wireless equipment, as well as a significant fade margin. Assuming a nominal operating frequency of 5.7 GHz with regulatory compliant power output (EIRP) from a base station of 33 dBm (2 Watts) and a client receiver with 30cm diameter antenna providing 23 dBi gain, the receive signal level (RSL) with clear line of sight would be -70.1 dBm at 7.5 km. Using a basic radio system, such as the Ubiquiti Rocket M5 access points and associated M5 customer receiver such as NanoBeam M5 system on a 20 MHz channel, and an assumed noise floor of 90 dBm, a client would connect at MCS13, providing a physical interface rate of 104 Mbps and a typical throughput rate of approximately 54 Mbps, which is safely above the NGA threshold and leaves a considerable fade margin assuming the access point is not over-subscribed.

# Assumptions and Constraints

As with all modelling approaches to wireless coverage, there are factors which could over-state or under-state coverage. Here is a summary of the key factors as they relate to this project: -

### Over-statement factors

- A small percentage of the national map data used was derived from low-resolution (10 to 30m) data, which could mean that obstructions to the wireless signal path calculations were missed. We estimate an error rate of up to 2% over-statement.
- Since the high-resolution data was produced between 2015 and 2017, it is likely that additional tree growth and new building works will have occurred in the intervening period which means that some wireless paths are now blocked. We estimate a resultant over-statement of <1% from this.
- Whilst it may be possible to receive a high-quality signal at a given property, it is possible that there is no suitable location on the property to mount a receiver due to the construction or location of the property. For example, waterside properties or those with unusual construction such as all-glass exterior can be very challenging.

### Under-statement factors

- In this exercise, we performed single-point line of sight tests to each EIRCODE property. In reality, it is possible that the Wireless Line of Sight to that one point may be obscured and therefore reported as no coverage, but if a receiver was mounted at a different point on the property, a connection could be established. We estimate an under-statement of 3-4% from this factor.
- We used a watershed method for wireless line of sight calculation which allows for little or no Near Line of Sight connections. Many modern radio systems using the diversity associated

with MIMO transmission allows for high quality connections to be established in Near Line of Sight operation and these have not been incorporated in the model. This is estimated to have an effect of up to 10%, but it is highly dependent on the technology used by the operator.

- We have assumed that 30cm dishes are used at the customer property to achieve an appropriate signal level. It is common practice to install 40cm dishes or larger, which have higher gain and therefore can receive a good signal at a longer range. Using larger dishes could increase the coverage from each access point substantially.

## Multi Dwelling Units (MDUs)

WISDM currently has a design constraint which means that the premises counted in coverage checks shows the same EIRCODE for all properties that have the same physical location (ie. Multi-dwelling units). This means that the coverage lists appear to have duplications. It was not possible to resolve this issue in the time available to complete the project.

LIDAR DSM Data Source coverage according to wirelesscoverage.com

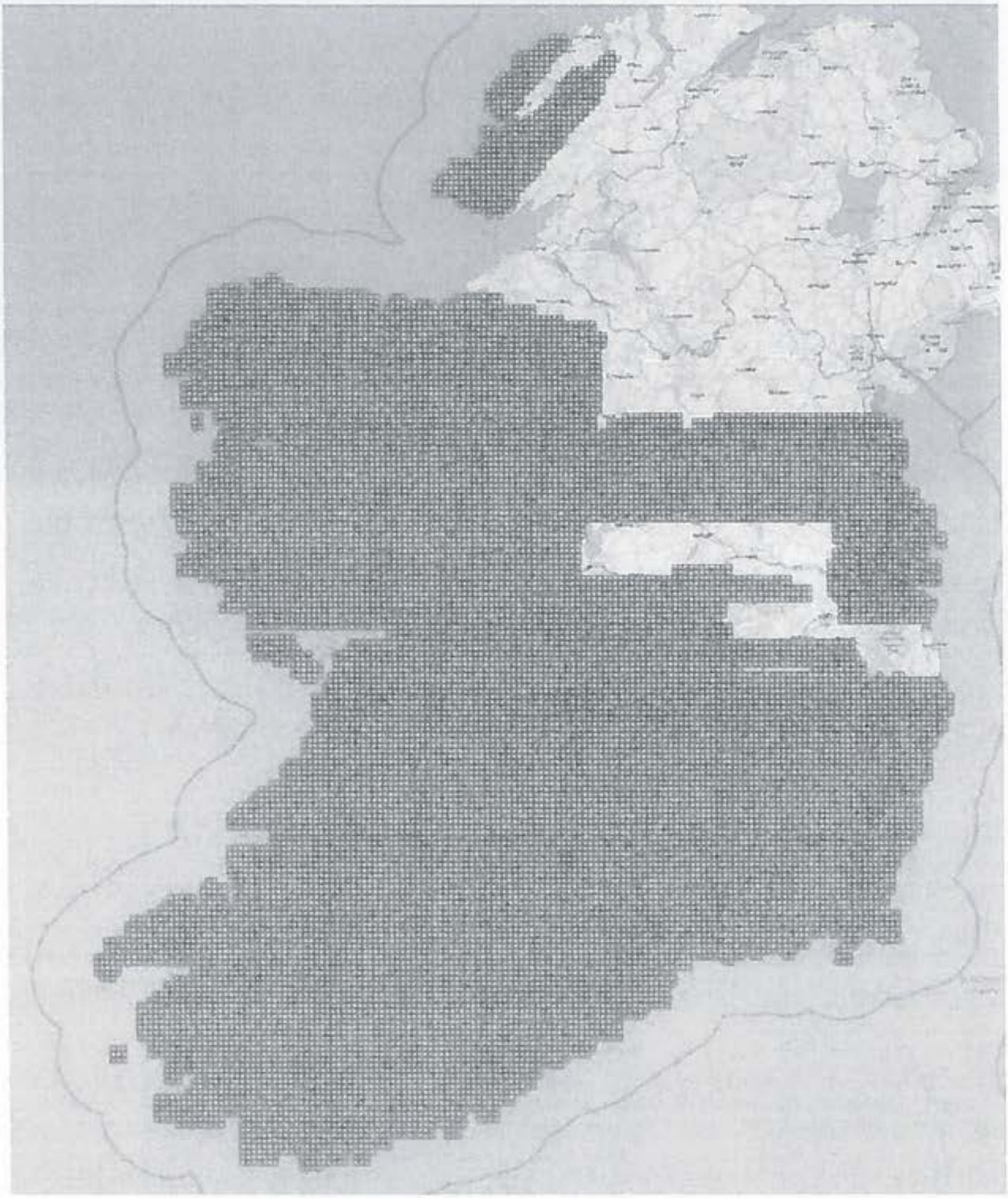


*Figure 1. Map of 1m DSM Data from Bluesky International, collected between 2015 and 2017*

*Figure 2. Example render of DSM Data showing trees, buildings and other surface features.*

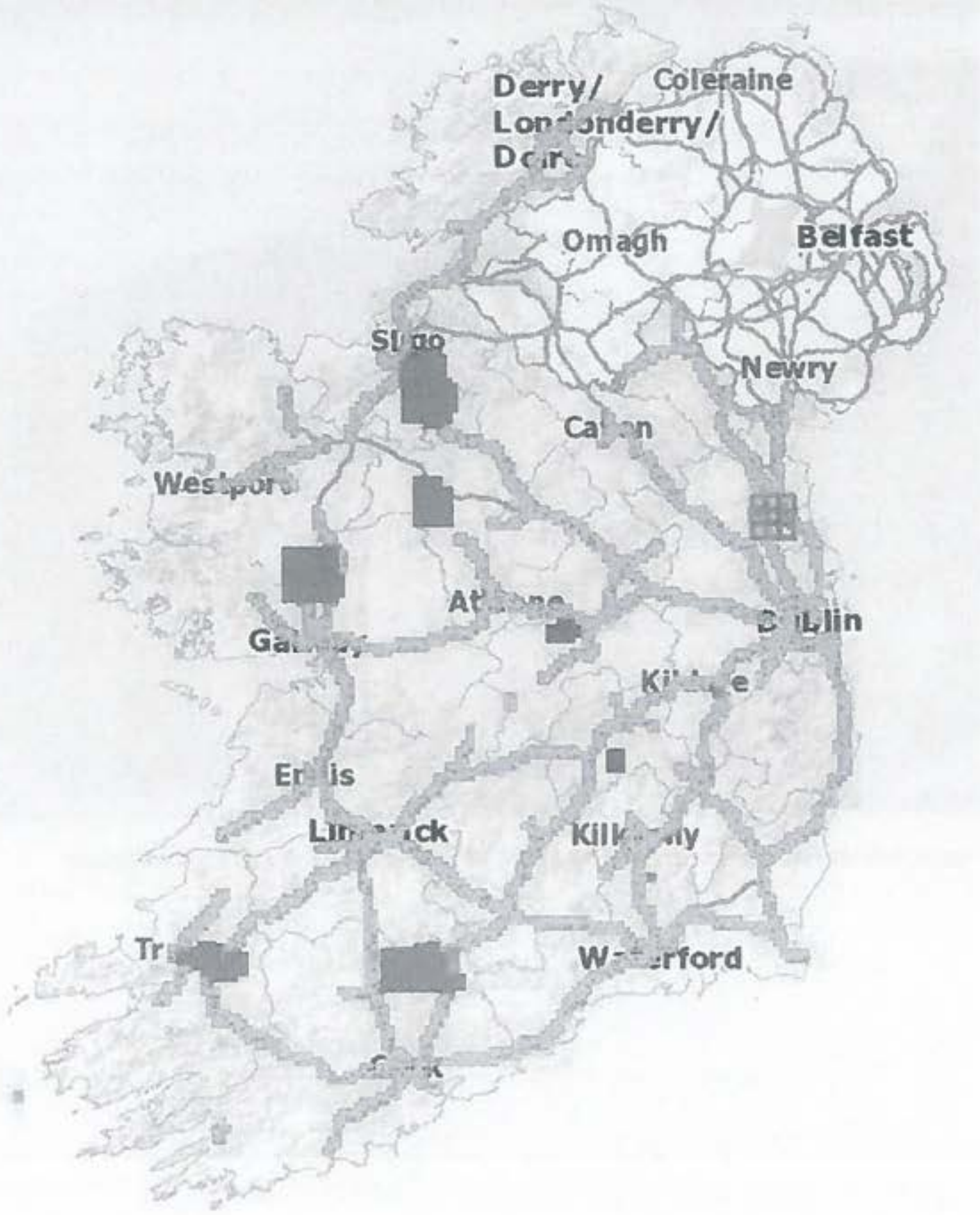



*Figure 3. Irish Government published Open LIDAR data areas that supplemented the proprietary LIDAR data.*


*Figure 4. Example of Open Topographic LIDAR data detail as published on data.gov.ie*

*Figure5. SRTM topographical data as captured and rendered by NASA*

# Wirelesscoverage.com WISDM™ Line of Sight Engine

## Highlights

Wireless coverage WISDM comprises of a family of ultra-high-performance wireless planning systems developed by Boundless Networks Ltd.

WISDM WISP Edition is an interactive planning and design system built to facilitate the creation of scalable, robust and performant fixed wireless networks for Wireless IPSs. It enables the rapid creation of 'Ideal' wireless networks over very large areas of thousands of square kilometres. It is well suited to rural expanses as well as mixed and urban environments too. Once an Ideal network has been designed, the network can be fine-tuned to consider build constraints and resiliency in real time.

WISDM can also be used to analyse the coverage of an existing wireless network and perform 'what-if' tests to plan ad-hoc extensions to a network to verify potential coverage and backhaul.

Using WISDM, a predictable coverage model can be prepared in hours and **detailed coverage of individual properties** can be predicted with an extremely high level of accuracy. Site planning and acquisition is accelerated by use of the interactive planning tools, allowing rapid decisions about mast location to be made with instant coverage impact reporting.

## Overview

WISDM comprises of several components and processes to complete the overall solution. At the heart of the system is a very high performance wireless Line of Sight (LoS) calculation engine. The LoS engine can calculate over 150 million wireless line of sight tests per second and can use a wide variety of terrain and surface obstruction data sets at any resolution.

Overall, WISDM WISP Edition performs the following tasks: -

1. Site Finder. This creates an 'Ideal' list of sites where masts could be located for optimum coverage for a given number of target premises passed from a target premises dataset. Target premises can be a list of all properties from a comprehensive source, such as Ordnance Survey AddressBase, or a subset of premises in say, a Government Intervention area. Assumptions can be used to set mast profiles which would include mast height and effective wireless range. For example, the Site Finder can be run with parameters which state that 20 locations could be built with 30m towers, then calculate how many 15m towers would be needed to pass a certain quantity of target premises.
2. Backhaul Modelling. The Backhaul Modeller analyses a Site Location dataset and performs line of sight tests between them to create microwave backhaul. Assumptions can be used to help plan for the style of links to be used. For example, links up to 5km can be coloured differently than links from 5km to 17km. This helps when planning a network that has optimum resilience, performance and operating costs due to the potential costs incurred to run licensed microwave links or fibre backbone.
3. Wide Area Network (WAN) Visualizer. The WAN Visualizer provides full-screen mapping to allow users to see the overall shape of a network and the distribution of different sized

towers and backhaul connections between sites. The WAN Visualizer can be called from the Site Coverage and Modelling system.

4. Site Coverage and Modelling System. This is an interactive web-based tool that allows planners to review the calculated Ideal Sites and move them on a map. At each point, the user can see instantly the impact of changes to coverage of Target Premises, as well as backhaul connections to other sites.
5. Backhaul Link Capacity Planning. Backhaul links can be described in terms of capacity and latency. Client connection volumes can also be applied to sites and WISDM will predict traffic load and volumes relative to transit or fibre injection points.

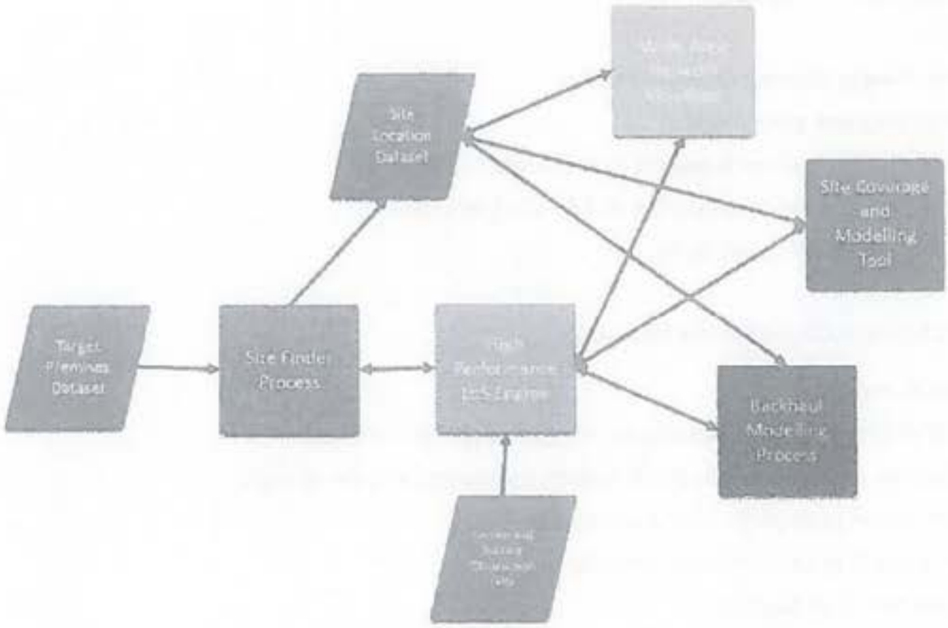



*Figure 6. WISDM System Schematic Overview*

## Wirelesscoverage.com WISDM LoS Engine

The WISDM LoS Engine is a custom-built high-performance wireless propagation calculator developed in Native C and CUDA. It is a multi-threaded application, currently running on a server farm at Wireless Coverage and is accessed via a C API. This currently operates with 5,000 GPU cores to achieve around 500 million line of sight transactions per second when creating viewsheds but can be scaled further as required.

The LoS Engine has forward and reverse lookup features that are optimised to illustrate coverage from a single point, or supply from multiple points. These features are so fast that they can be operated in real time and take into consideration precision line of sight calculations as well as frequency, loss (according to ITU recommendations) and 3d antenna patterns for both transmitter and receiver.

## Line of Sight Engine Technical Overview

Specific variants of the Line of Sight Engine exist for Forward (Viewshed) and Reverse (Best AP) coverage over large areas at any sample resolution. Below is an example of point to point request, but this is replicated over larger areas for the Forward and Reverse viewshed methods, where a map grid is also specified. The application uses the following parameters as input to each request via an API: -

- Site A Lat/Lon
- Site A transmitter height above ground in metres
- Site A transmitter power dBm
- Site A transmitter antenna gain in dBi
- Transmit frequency in MHz
- Scanning resolution in metres
- Site B Lat/Lon
- Site B receiver height above ground in metres
- Site B receiver antenna gain in dBi
- Percentage of first Fresnel required for partial line of sight in %
- Percentage of first Fresnel required for no line of sight in %
- Antenna Model (used for beam pattern)

The response for each request includes the following: -

- Link distance in metres
- Pass Status (Full Line of Sight, Partial Line of Sight or No Line of Sight)
- Predicted Receive Signal Strength (RSL) in dBm, assuming full Line of Sight
- Azimuth from Site A in degrees from true North
- Azimuth from Site B in degrees from true North
- Elevation from Site A in degrees
- Elevation from Site B in degrees
- Antenna Model (used for beam pattern)
- Optional link ground profile .PNG image file, illustrating the link profile and first Fresnel shape

Point A name: Point A
Point B name: Point B
Coordinates of A: 53.673302°, -2.664143°
Coordinates of B: 53.645783°, -2.573456°
Height of A: 20 m
Height of B: 10 m
Power: 20 dBm
Antenna gain of A: 13 dBi
Antenna gain of B: 23 dBi
RF frequency: 5825 MHz

Estimated RSSi: **-69.37 dBm**
Azimuth from A: **117.05°**
Azimuth from B: **297.05°**
Elevation from A: **1.38°**
Elevation from B: **-1.38°**
Link distance: **6734.22 m**

*Figure 7. Sample LoS Engine Input and Output*

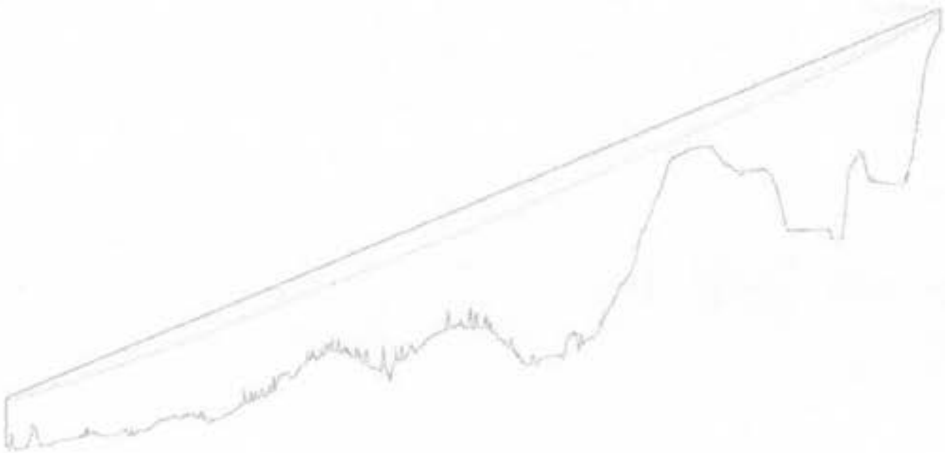


*Figure 8. Sample LoS Ground Profile Image*

## Mathematical and Technical LoS Model

A DSM elevation raster (of chosen resolution) of the target area is loaded into memory (~11GB GeoTIFF file equates to around 6,500 sq miles, imported with GDAL C library) into a flat array of 32-bit floats in a geodetic WGS84 latitude / longitude grid. This data stays loaded in memory for every call of the function. A function exists to return the height in metres above sea level for any given latitude + longitude using bilinear interpolation in the grid. This allows for very fast indexed surface elevation lookups for any point in target area with high resolution.

64-bit integers are used for indexing coordinates and x87 80-bit floating-point numbers are used in coordinate calculations.

2 functions exist, geodetic_to_ecef and ecef_to_geodetic for converting between ellipsoidal WGS84 coordinates and cartesian ECEF coordinates.

geodetic_to_ecef is an implementation of Section 10.2.1 from B. Hofmann-Wellenhof, H. Lichtenegger, J. Collins' GPS - theory and practice as follows:

$$
\begin{aligned}
N(\phi) &= \frac{a^2}{\sqrt{a^2\cos^2\phi + b^2\sin^2\phi}} \\
X &= (N(\phi) + h)\cos\phi\cos\lambda \\
Y &= (N(\phi) + h)\cos\phi\sin\lambda \\
Z &= \left(\frac{b^2}{a^2}N(\phi) + h\right)\sin\phi
\end{aligned}
$$

where $h$ is height in metres; $\phi$ is latitude; $\lambda$ is longitude; $a$ is the Earth's equatorial radius in metres; $b$ is the Earth's polar radius in metres; $(X,Y,Z)$ is the cartesian ECEF coordinate.

ecef_to_geodetic is an implementation of J. Zhu's "Exact conversion of earth-centred, earth-fixed coordinates to geodetic coordinates" formula as follows:

$$
\begin{aligned}
r &= \sqrt{X^2 + Y^2} \\
E^2 &= a^2 - b^2 \\
F &= 54b^2Z^2 \\
G &= r^2 + (1 - e^2)Z^2 - e^2E^2 \\
C &= \frac{e^4Fr^2}{G^3} \\
S &= \sqrt[3]{1 + C + \sqrt{C^2 + 2C}} \\
P &= \frac{F}{3\left(S + \frac{1}{S} + 1\right)^2 G^2} \\
Q &= \sqrt{1 + 2e^4P} \\
r_0 &= \frac{-(Pe^2r)}{1 + Q} + \sqrt{\frac{1}{2}a^2(1 + 1/Q) - \frac{P(1 - e^2)Z^2}{Q(1 + Q)} - \frac{1}{2}Pr^2} \\
U &= \sqrt{(r - e^2r_0)^2 + Z^2} \\
V &= \sqrt{(r - e^2r_0)^2 + (1 - e^2)Z^2} \\
Z_0 &= \frac{b^2Z}{aV} \\
h &= U\left(1 - \frac{b^2}{aV}\right) \\
\phi &= \arctan\left(\frac{Z + e'^2Z_0}{r}\right) \\
\lambda &= \operatorname{arctan2}(Y, X)
\end{aligned}
$$

where $(X,Y,Z)$ is the cartesian ECEF coordinate; $h$ is height in metres; $\phi$ is latitude; $\lambda$ is longitude; $a$ is the Earth's equatorial radius in metres; $b$ is the Earth's polar radius in metres; $e$ is the Earth's first orbital eccentricity; $e'$ is the Earth's second orbital eccentricity.

The 3D cartesian coordinates of each radio is found by sampling the ground elevation of the two points and adding on the mast heights, and then using geodetic_to_ecef. The accurate straight-line distance between the two radios can be found by using $\sqrt{dx^2 + dy^2 + dz^2}$.

The straight line between each $(x,y,z)$ position is divided into linear interval points at the desired scan resolution. These points are then converted back into (latitude, longitude, height) WGS84 coordinates using ecef_to_geodetic.

The surface elevation at each of these WGS84 points is sampled and the resulting coordinates + height are converted back into ECEF coordinates.

The resulting 3D ECEF coordinates should mostly be in a flat plane and represent the elevation profile of the terrain under the line between the two radios, including the curvature of the Earth.

These coordinates are transformed into flat 2D coordinates by rotating them through 3 axes using transformation matrices. Once they are rotated to a flat plane against the axes, the resulting *Z* coordinate will be approximately zero and is discarded to produce 2D coordinates.

A 2D straight line is plotted between the two radio coordinates and perpendicular to this line, points are calculated and plotted for the first Fresnel zone and given threshold percentages within the Fresnel zone. The radius $r$ in metres of the first fresnel zone is calculated using:

$$r = \sqrt{\frac{cd(t-d)}{1000000ft}}$$

where $c$ is the speed of light in $ms^{-1}$; $d$ is the distance along the line in metres; $t$ is the total distance between the two radios; $f$ is the frequency in megahertz.

Intersection with the surface profile polygon and the plotted Fresnel threshold points is tested using binary search + linear interpolation.

The basic RSL $s$ in decibels is calculated using:

$$l = 92.5 + 20\log_{10}\left(\frac{d}{1000}\right) + 20\log_{10}\left(\frac{f}{1000}\right)$$
$$s = p + g_1 + g_2 - l - t$$

where $l$ is the free-space path loss in decibels; $d$ is the distance in metres; $f$ is the frequency in megahertz; $p$ is the power of the transmitter; $g1$ and $g2$ are the antenna gains of each antenna; $t$ is the transmission line loss, assumed to be 1 decibel. Further ITU-R attenuation models are applied for appropriate bands, but not described in this document.

## A2 Future Deployment Information

**Due to the lack of notice, timing of the consultation period in peak holiday season, short initial consultation period and short extensions to the consultation period we have had insufficient time to present our exciting future plans for expanding our network. We will continue to grow our network and invest in new technologies in the same manner as we have done in the past. It is profoundly regrettable that the DCCAE NBP Team wilfully disregarded the best practices document on public consultations that another government department DPER had gone to the trouble of issuing on the topic of running a public consultation. Specifically DCCAE's NBP Team ignored the guidelines around giving more time for a consultation period so that smaller businesses would be given a fair opportunity to respond given the inherent constraints on resources that small business have. A copy of the DPER guidelines can be downloaded from the following url;**

https://www.gov.ie/en/publication/e9b052-consultation-principles-and-guidance/

## A3 Future Financial Information

The comments made in A2 are repeated here. More importantly, it is impossible for us and other similarly placed FWA operators to obtain the certainty of financing required by DCCAE's Assessment Criteria until DCCAE has accepted that we are providing NGA service and ruled our coverage area out of the currently proposed NBP. Intervention Area. By definition therefore, because the DCCAE has placed this impossibly high bar in our way, we are blocked as a result from being able to comply with DCCAE's requirements for future plans and therefore any future plans we and other existing FWA operators have can be totally disregarded by DCCAE. We cannot and do not accept that the EU's State Aid Guidelines are intended to be applied in this way.

| | |
|---|---|
| **From:** | [redacted] |
| **To:** | NBP Mapping |
| **Subject:** | Unable to receive NGB Services |
| **Date:** | 16 September 2019 10:46:27 |



Hi

I am writing to you to inform you of the lack of available services to myself and the other 3 homes surrounding mine. I have previously contacted Eir in relation to Fibre broadband and was informed that there were no plans of providing a fibre service due to our location.

My Eircode is [redacted] and my closest neigbours is [redacted]. I am currently using vodaphone mobile broadband as my service provider as they have the best coverage for my location. I am in the light blue area for state intervention as we are too far from the phone exchange to receive fibre to the home. The service i currently receive is affected by weather on a daily basis. My property is a new build with network cable access accessable from the outside wall of my home ready for future services.

I just wanted to make you aware that I am eager to receive a better service.

Regards

[redacted]

[redacted]