[redacted]

From: [redacted]
Sent: 20 September 2019 16:05
To: NBP Mapping
Subject: Galway City residences unable to get access

Follow Up Flag: Follow up
Flag Status: Completed

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Dear NBP mapping

I can confirm residents at [redacted] area Galway City are unable to connect to high speed broadband and should be included in the intervention area. The residence have attempted to get access from various communication providers and made representations to local councillors but are still unable to get access.

It's my understanding a number of locations in the area have difficulty getting High Speed broadband (over 30mb)

Best regards

[redacted]

[redacted]
Broadband officer / *Oifigeach Leathanbhanda*
Galway City Council / Comhairle Cathrach na Gaillimhe
College Road / Bóthar an Choláiste
Galway / Gaillimh
[redacted]
T: [redacted]
M: [redacted]
Email/Rphost : [redacted]

Gaillimh - Príomhchathair Chultúir na hEorpa 2020

Galway European Capital of Culture 2020

Galway2020.ie

Tá fáilte roimh chomhfhreagras i nGaeilge nó i mBéarla.

Correspondence is welcome in Irish or in English.

From: [redacted]
To: NBP Mapping
Subject: Broadband in [redacted] Co. Meath
Date: 19 September 2019 20:51:17

Hello,

I am writing to you in relation to the absolutely SHOCKING broadband service we are availing of in [redacted]

We are currently recieving download speeds of approx. 0.8mbps. This is making attending online lectures, working from home or general web surfing absolutely impossible.

There is a couple of new developments at the end of our road that have been upgraded to fibre but it appears that unless you're a new build, you don't matter.

Its 2019, we are only on the outskirts of a large port town and close in proximity to Dublin, yet you would think we were in the middle of nowhere.

We have been lied to by several providers who have said they can most definitely provide a better service, only for the engineer to laugh when he comes to our house saying its impossible.

No one appears to actually know anything about the NBP and of course we don't even have a timline of when we can expect work to begin.

If you would like to discuss this further, please let me know [redacted]

It would be fantastic if you managed to bring all of Ireland into the 21st century.

Many thanks
[redacted]

From: [redacted]
To: [redacted]
Subject: Re: Fibre Broadband Availability
Date: 13 September 2019 11:41:31

[redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Hi,
I was directed to this email address by National Broadband Plan Division.
As stated in below email I am living in dublin at following address,

[redacted]

I did inquire about fiber broadband with all major broadband providers and all of them confirmed that high speed broadband is not available in my area. I further learnt that my residence is in 'Blue' zone where private internet providers are supposed to make infrastructure available.
I was asked to forward any correspondence with internet providers to this email address, since all my conversations were on phone I can not forward you any document, however please find attached 'speed availability check' snapshots from major internet provider. maximum download speed available to my residence is upto 24mbps (realized speed is somewhere around 7mbps) and upload speed is 0.02 mbps.

Thanks
[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

From: [redacted]
To: [redacted]
Subject: New Submission
Date: 18 September 2019 16:08:34

Conclusion of the Mapping Exercise

[redacted]

[redacted]

National Broadband Plan

Conclusion of the Mapping Exercise

Submissions: nbpmapping@dccae.gov.ie

The Department of Communications Climate Action and Environment is running a consultation on the National Broadband Plan Map.

We would like to hear from you if you have a problem accessing a high speed broadband service for your home or business.

Issues may include placing an order, getting connected, and/or getting the service you have ordered.

Name:
[redacted]

[redacted]

[redacted]

[redacted]

Location on NBP Map
Blue in Light Blue

Detail of correspondence with service providers:

Current provider Eir (FTTH). Connected in November 2018 and speeds are very poor. Signed up to 300Mbps but not getting it. Paid connection fee. Numerous calls to customer care - have not resolved the issue. Will be cancelling come November 2019. Very dissatisfied. Spent a lot of money talking to customer care.

Detail of issue experienced:

Current provider Eir (FTTH). Connected in November 2018 and speeds are very poor. Signed up to 300Mbps but not getting it. Paid connection fee. Numerous calls to customer care - have not resolved the issue. Will be cancelling come November 2019. Very dissatisfied. Spent a lot of money talking to customer care.

In some cases queries may need referral to operators after the consultation has concluded.

Has permission been given to pass on details supplied to the relevant operator(s) in the course of investigating any issues?

Yes

Airwave Internet

[redacted]

www.airwave.ie

[redacted]

2019

Airwave Internet

SUBMISSION ON BROADBAND COVERAGE

[redacted]

Contents

A1 Technical Information

1 Introduction

We have built our network around having good bandwidth with consistent and low latency, 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. Those technological advances have included interference mitigation, a feature which the interference relates questions in DCCAE's non upgrade 2015 Assessment Criteria e definition fails to recognise.

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.

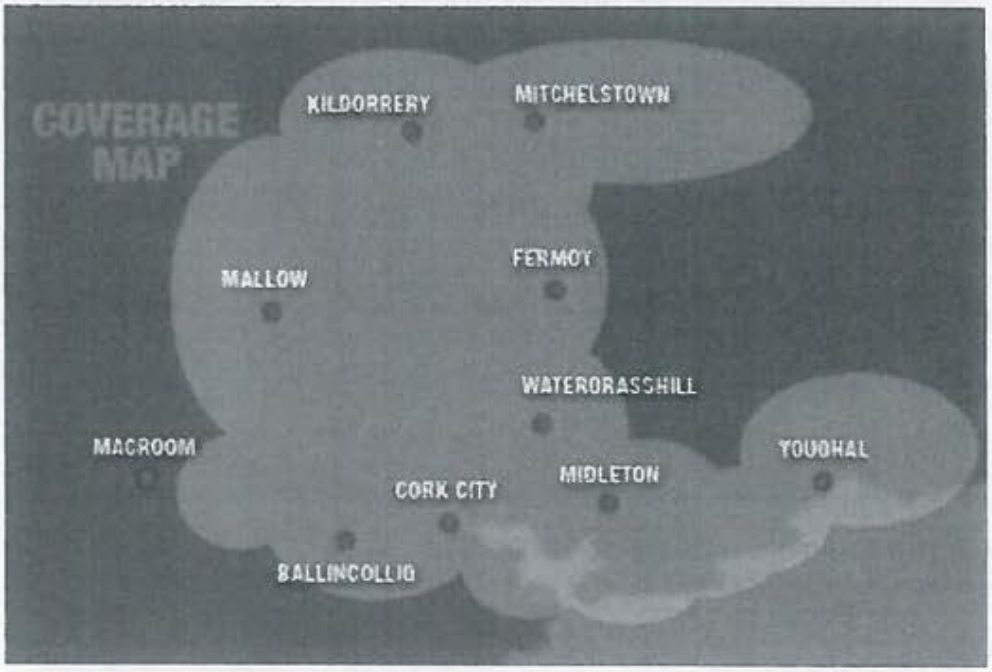
We also support business users with remote working solutions through VPNs, Remote Desktop Environment and cloud-based productivity suites. Our customers report excellent results with video conferencing which allows for more remote working less commuting, less traffic congestion, reduced carbon footprint 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 covers about half the area of Cork County – predominately East Cork and North Cork. The region is typical of rural Ireland, in that it is a mixture of regional towns (Midleton, Youghal, Fermoy, Mallow) and small villages. It is the hinterland of these that provide the mainstay of our customer base.

Our network is multi-homed and uses 4 upstream routes to the internet for maximum redundancy. We are POP'ed at CIX, which is the premier data centre outside of Dublin and from there we use a mixture of licensed microwave and fibre backhaul to serve the regions.

We are members of INEX and have been providing our own telephony service since 2009



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 450 and ePMP platform 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 4 of 90-degred Canopy 450mAP(Medusa), 450iAP, ePMP3000 or ePMP2000 advanced sector antennas to provide coverage in the area. If the site has a smaller azimuth coverage, then we will match the number of panels to suit. 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.
- Replacing Canopy 450iAP with the Canopy 450m Medusa panel (400Mbps +)
- Replacing Cambium ePMP 2000 AP with ePMP3000

The additional capacity is added on an ongoing basis to maintain the performance levels and expectations to ensure NGA Performance during the Busy Hour.

We should point out that not all our customers are prepared to pay for NGA service at this time. As a result, whilst we are ready willing and able to provide NGA service to any customers who want it and are prepared to pay our reasonable and competitive charges, we do not at present have to scale our network on the basis that all our customers have be provided with NGA service. Instead, as and when they migrate to NGA we are able to upgrade any necessary parts of our network in order to accommodate that process as we have clearly done in the past

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 selected Cambium sectors and client units. We use Mikrotik Routers to forward customer Internet traffic inside Layer 2 Tunnel Overlay on a Redundant layer 3 Routed network.

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

- 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
-

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:

- 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

1.2.2 Sector Technology Deployed

We deploy sectoral transmitters according to the design and strategy outlined earlier. We utilise Cambium 450mAP (Medusa), 450iAP, ePMP3000 and ePMP2000 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:

- 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/

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 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
- Cambium 450 27dbi 5Ghz Client units supporting throughputs of up to 100Mbps down and 40Mbps uplink on 20Mhz
    - https://www.cambiumnetworks.com/products/pmp-distribution/pmp-450-subscriber-module/
- Cambium 450b 5Ghz Client units (both standing and high gain varieties) supporting throughputs of up to 250Mbps down and 50Mbps uplink on 20Mhz
    - https://www.cambiumnetworks.com/products/pmp-distribution/pmp-450b/

1.3.Backhaul Network Technology and specification of Backhaul Technologies

Our Backhaul is heavily dependent on Fiber optic technology. 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.

- 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
- Cambium PTP670 – 5Ghz 450Mpbs throughput
  - https://www.cambiumnetworks.com/products/backhaul/ptp-670/

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

For long range links we utilize the following :

- Ceragon IP20F – different frequency bands – links up to 35km – up to2Gbps on a single link
  - https://www.ceragon.com/products/fibeair-ip-20f
- 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

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

- 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

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

Our network is POP'ed at CIX (Cork Internet Exchange) and as such is meshed with multiple different upstream providers

1.3.2.3 [CIX] Backhaul

We have [x] 10G Fully Managed Redundant IP Transit from CIX

We have [x] 10G Link to INEX – CORK

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 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).

For CPE we use the Cambium platform – either Canopy 450 or ePMP

- 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
- Cambium 450 27dbi 5Ghz Client units supporting throughputs of up to 100Mbps down and 40Mbps uplink on 20Mhz
    - https://www.cambiumnetworks.com/products/pmp-distribution/pmp-450-subscriber-module/
- Cambium 450b 5Ghz Client units (both standing and high gain varieties) supporting throughputs of up to 250Mbps down and 50Mbps uplink on 20Mhz
    - https://www.cambiumnetworks.com/products/pmp-distribution/pmp-450b/

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

1.6.1 Table of Location of Base stations (INFORMATION IS COMMERICALLY CONFIDENTIAL)

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

Commerically-Confidential-Attachment – List of Sites – Airwave – public

(Customer sensitive data only removed)

1.6.2 Table of Location of Connected Clients (INFORMATION IS COMMERICALLY CONFIDENTIAL)

List of Connected customers in the form of GPS Coordinates .

Commerically-Confidential-Airwave_List of Connected Clients - by GPS - public.csv

(Customer sensitive data only removed)

1.6.3 Table of Location of Covered Premises Physically Tested on Site (GPS coordinates) (INFORMATION IS COMMERICALLY CONFIDENTIAL)

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.

Commerically-Confidential-List of previous customers by GPS-public.csv

(Customer sensitive data only removed)

1.6.4 Table of Location of Premises Passed based on High Resolution LIDAR and DSM data (eircodes only) (INFORMATION IS COMMERICALLY CONFIDENTIAL)

List of eircodes passed with current NGA capability attached

Commerically-Confidential-Airwave_NGA_Detail-public.xlsx

(Customer sensitive data only removed)

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

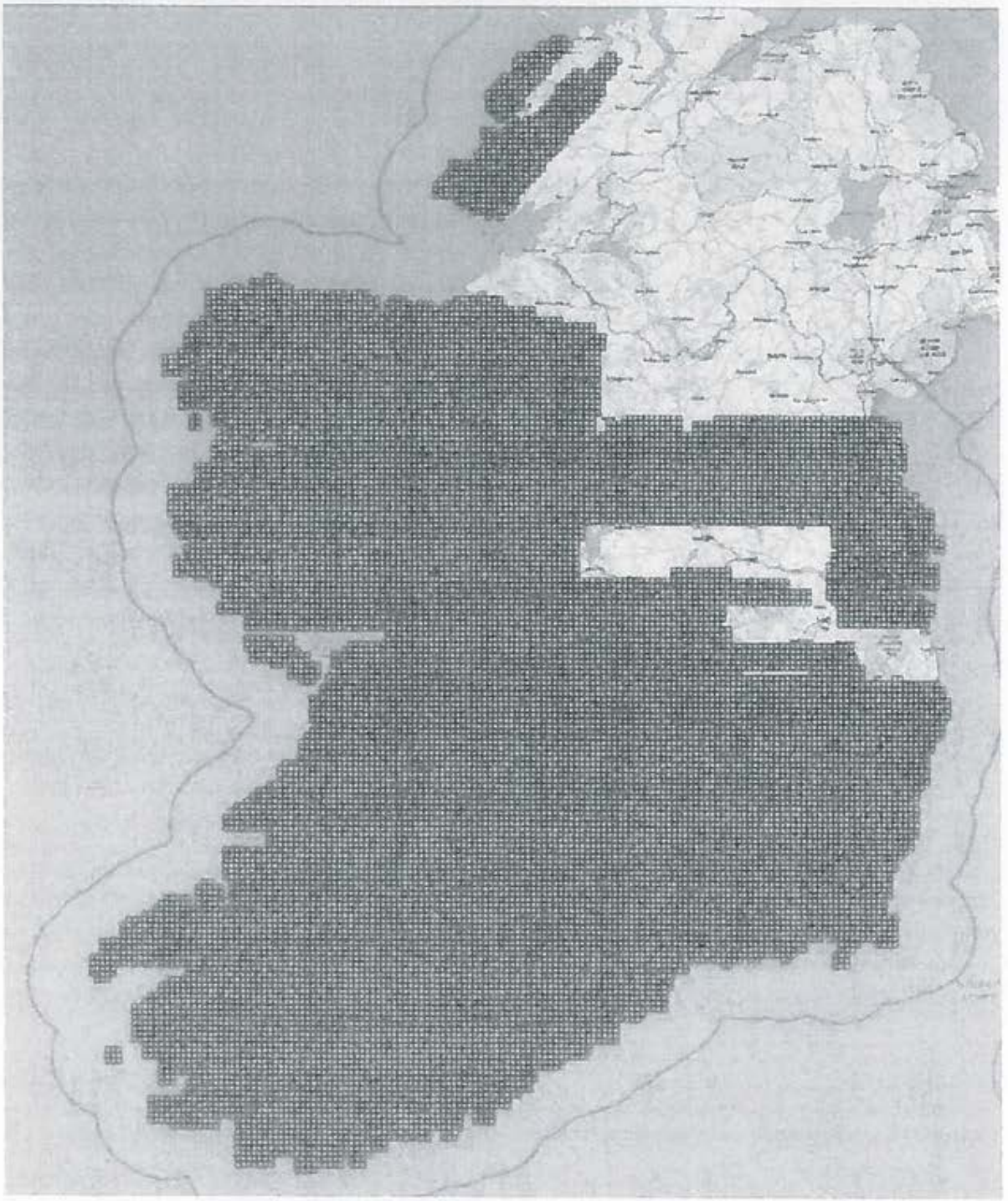


Figure 1. Map of 1m DSM Data from Bluesky International, collected between 2015 and 2017

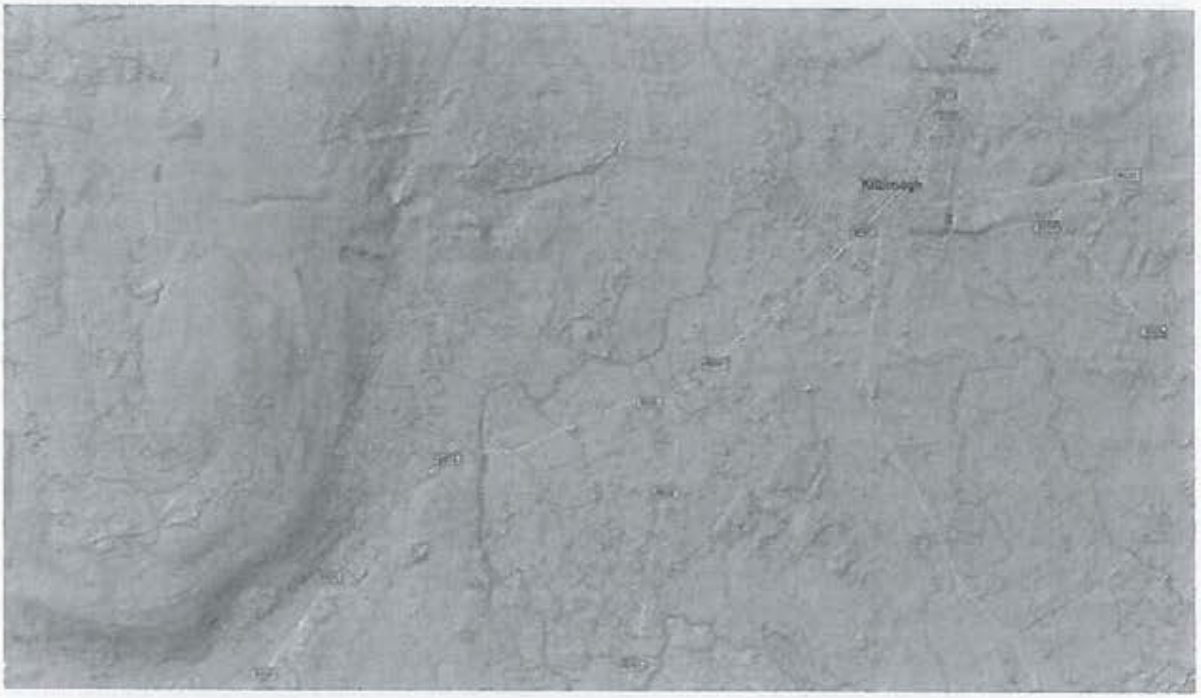


Figure 2. Example render of DSM Data showing trees, buildings and other surface features.

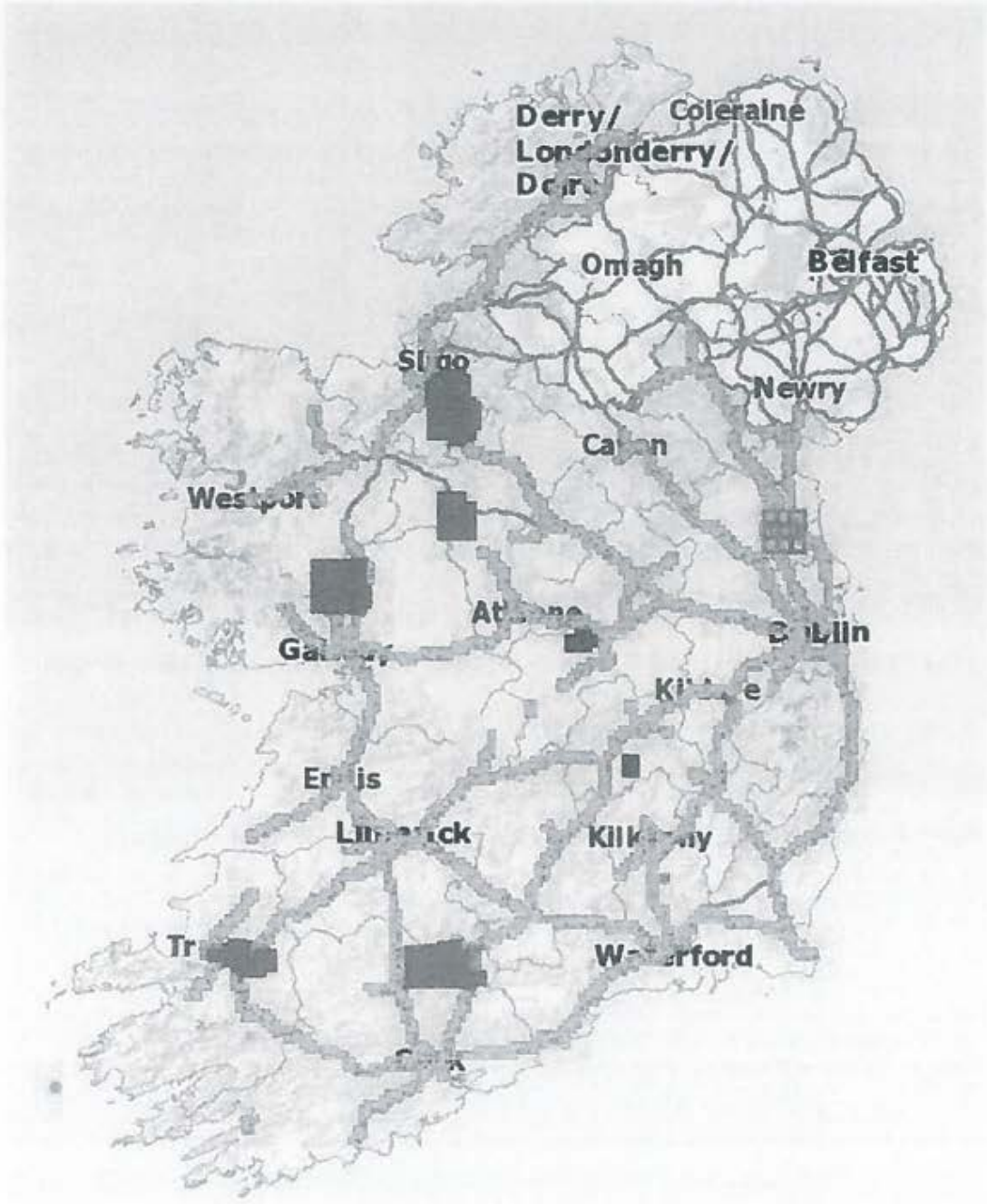


Figure 3. Irish Government published Open LIDAR data areas that supplemented the proprietary LIDAR data.

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

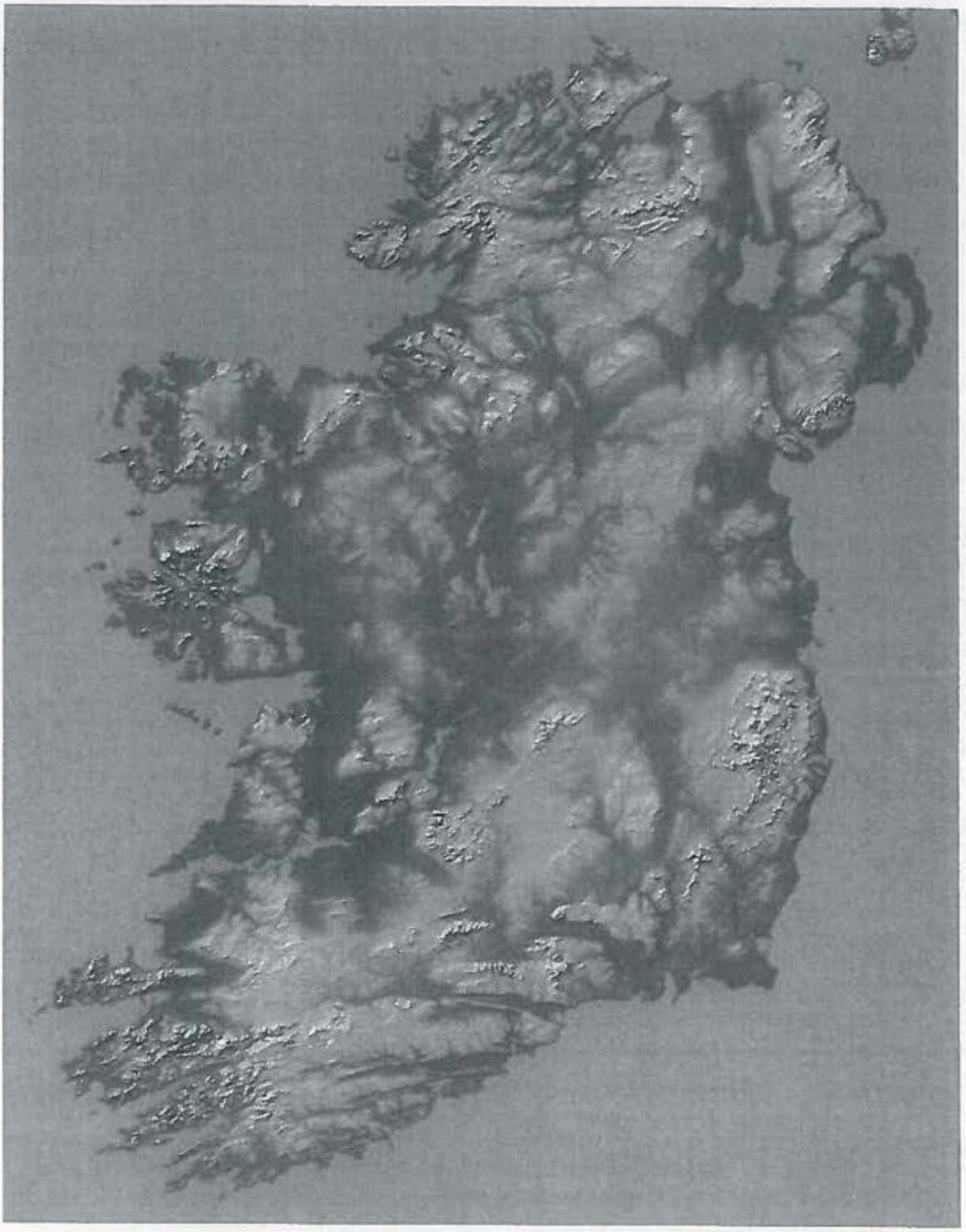


Figure5. SRTM topographical data as captured and rendered by NASA

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.

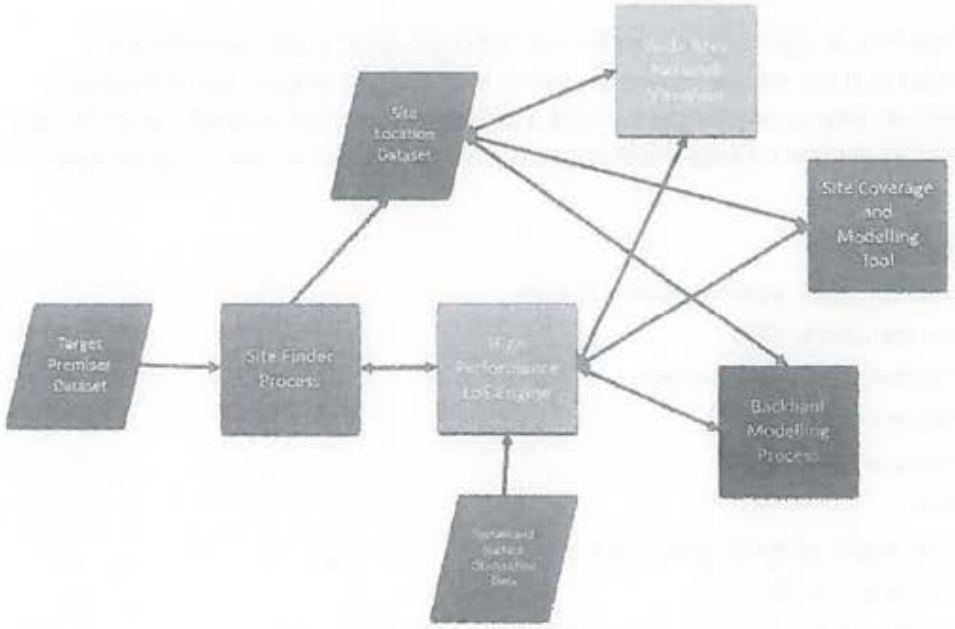


FIGURE 1 WISDM SCHEMATIC SYSTEM OVERVIEW

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

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 2 SAMPLE LOS ENGINE INPUT AND OUTPUT

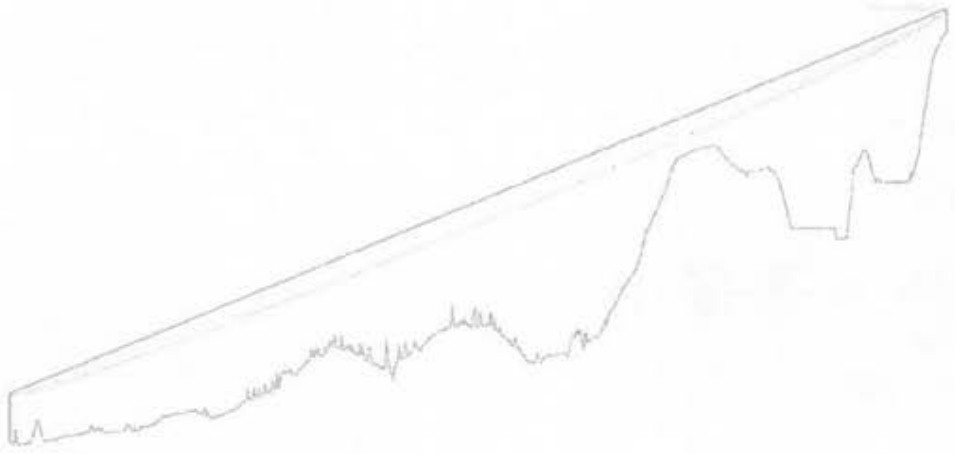


FIGURE 3 SAMPLE LOS GROUND PROFILE IMAGE

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:

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

where h is height in metres; 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:

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

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.

Future Deployment Information

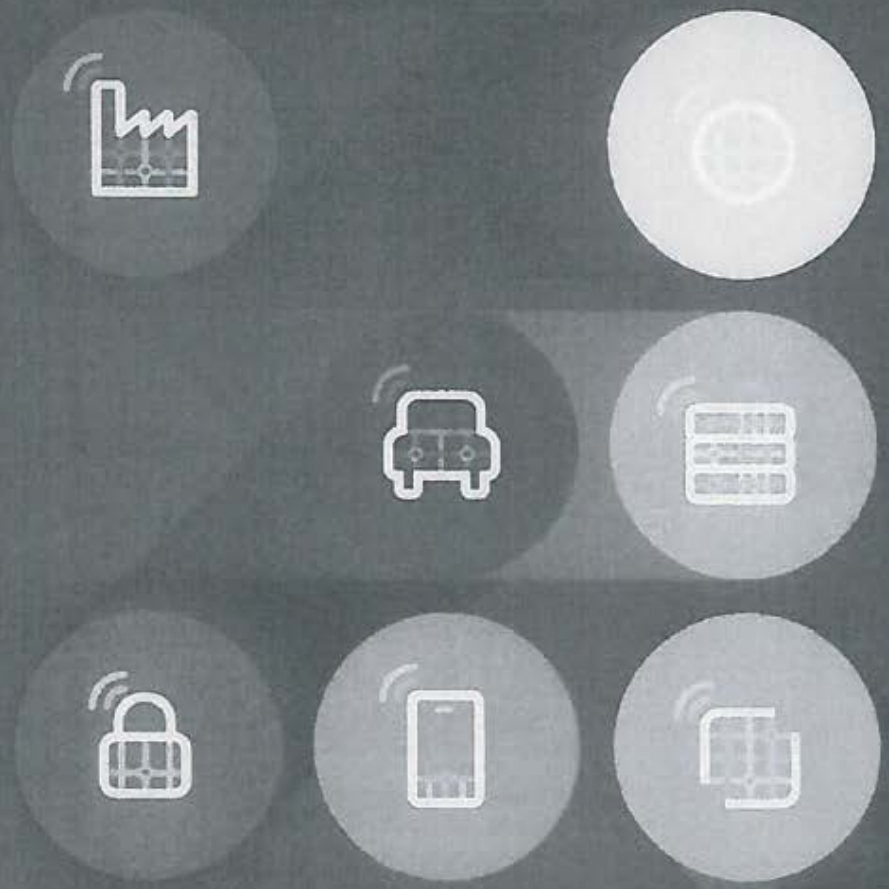
Due to the lack of notice, timing of the consultation period in peak holiday season and short extension we are unable to produce extensive plans. We will continue to grow our network in a organic fashion as to date.

It has been impossible to make detailed plans for many years as the prospect of NBP unjustly grant aiding another provider to take our customers means that any business plan would be made redundant.

How can we make business plans or avail of investment in today's environment of the state grant aiding NBI to build a network into areas we already serve? What is the incentive for a business to invest?

Aurora
Network

Aurora
TELECOM



Part of ervia group

About

Aurora Telecom was established in 2000 to utilise duct infrastructure adjacent to the natural gas network and is Ireland's leading backhaul dark fibre service provider. Aurora Telecom is a division of Gas Networks Ireland (GNI) which is a subsidiary company of Ervia, a group 100% owned by the Irish State. Ervia manages and maintains two of Ireland's strategic national resources – the country's water and gas infrastructure. We own and operate a carrier neutral, open access dark fibre network with an ultra-high fibre count. Our network is the most modern, carrier grade, backhaul dark fibre network in Ireland. It has been constructed using the latest fibre optic technology.

860km

of fibre network linking Dublin and 11 locations throughout the country

165km

of fibre network linking Galway and Killala subsea CLS

100km

of Network to connect to AEC2/Havfrue CLS by end of 2019

Aurora Telecom is a carrier and enterprise service provider. We supply to carriers and telecom operators (fixed / wireless / mobile), wholesale providers, corporate and public sector customers. Our customers receive bespoke, dedicated, un-metered and completely secure, high-speed fibre connectivity. Our network delivers superior performance and provides a reliable and secure base layer for carriers and enterprise to deliver their connectivity solutions.

100%

same grade of fibre throughout the network Corning G.652.d single-mode fibres E9/125 SMF-28e+

Introduction

Secure Network

The Aurora network is the most secure in country as a result of three key factors:

1) Large sections of the Aurora Dublin Metropolitan Area and the Aurora National network are constructed alongside the Gas Transmission pipelines. These routes are flown by a pipeline surveillance team on a fortnightly basis in order to identify 3rd party works adjacent to the pipeline.
2) Where the Aurora network is not constructed adjacent to a gas pipeline, monthly surveillance is undertaken via drive-by patrols over the entire route.
3) Gas Networks Ireland operates a "Dial-Before-You-Dig" service to other utility companies, contractors and designers. This service provides location information for all the Gas Networks assets, including Auroras. This ensures that any works being undertaken have visibility of the Gas Networks asset in advance and can ensure that preventative measures are put in place to avoid disruption to same.

All this equates to a 99.999% Service availability

Datacentres

The Aurora network provides interconnection with all key data centres both in Dublin and nationally and with the benefit of primary interconnections with local, national and global telecommunications carriers. The increasing demand for our fibre services in the Irish market is being driven by the growth in the data centre development. The Aurora network in Ireland is of the highest quality with best-in-class security; resilience; performance; latency and as such it is particularly suitable for high capacity data transportation and international connectivity. This makes it the perfect solution for the fibre requirements of data centres

Subsea connections carrier of choice

It is crucial for subsea carriers to ensure they have access to a backhaul dark fibre provider to traverse the country. Carriers recognise that Aurora are willing to work with them at an early stage to identify landing sites based on the optimum location to connect with the Aurora network. As a result, Aurora is the preferred carrier of choice for the recent and proposed submarine cables (including, Aquacomm's $400m transatlantic cable linking the US and Killala; and the latest Havfrue/AEC2 Transatlantic cable).

Fibre

100% - Same grade of fibre throughout the network Corning G652.d single-mode fibres E9/125 SMF-28e+

National Network constructed for back-haul services with Spans of 3km+ between Splice enclosures. Blown Fibre reduces the about of enclosures required reducing latency & fibre loss.

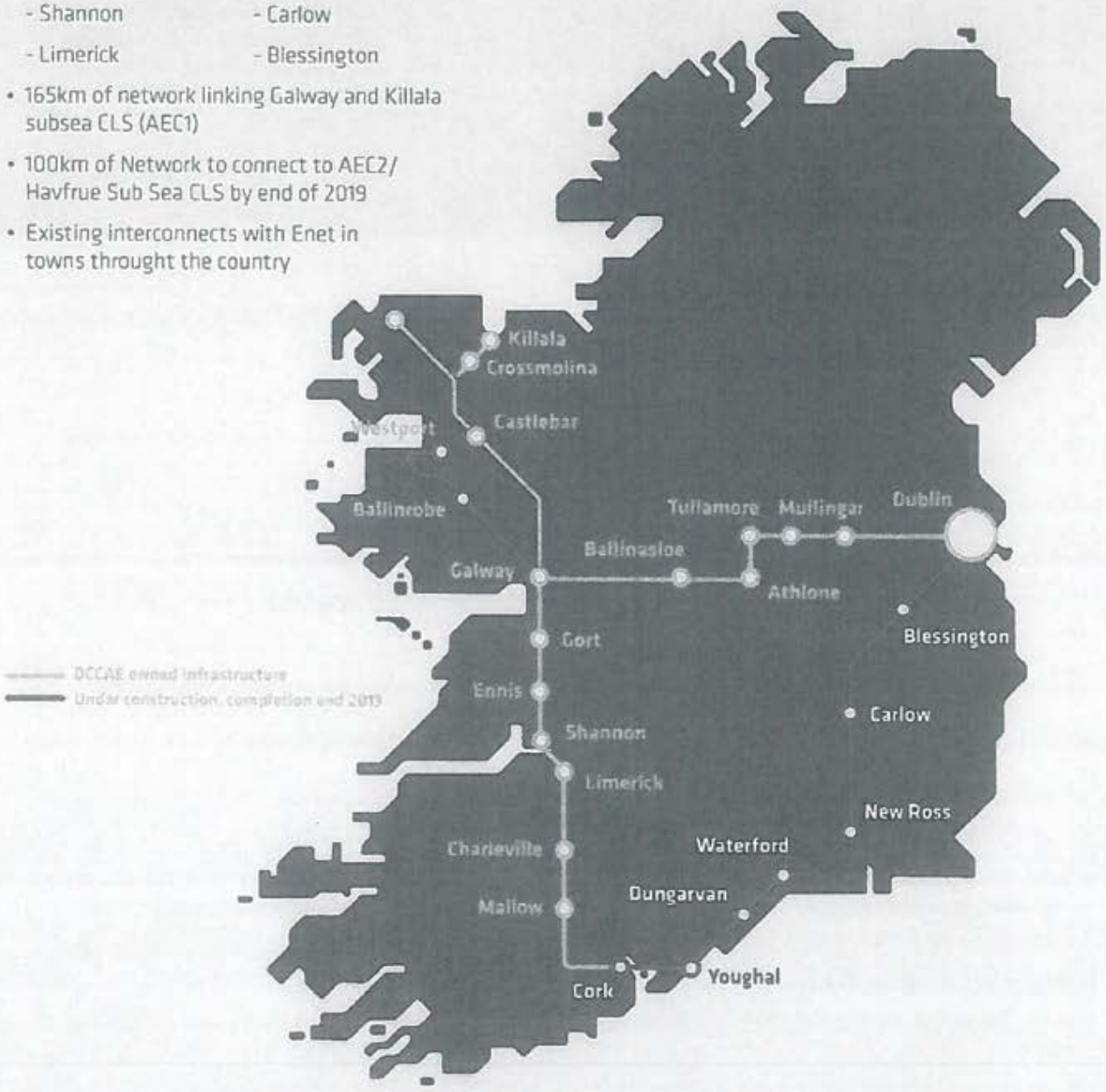
Key Features of our network include

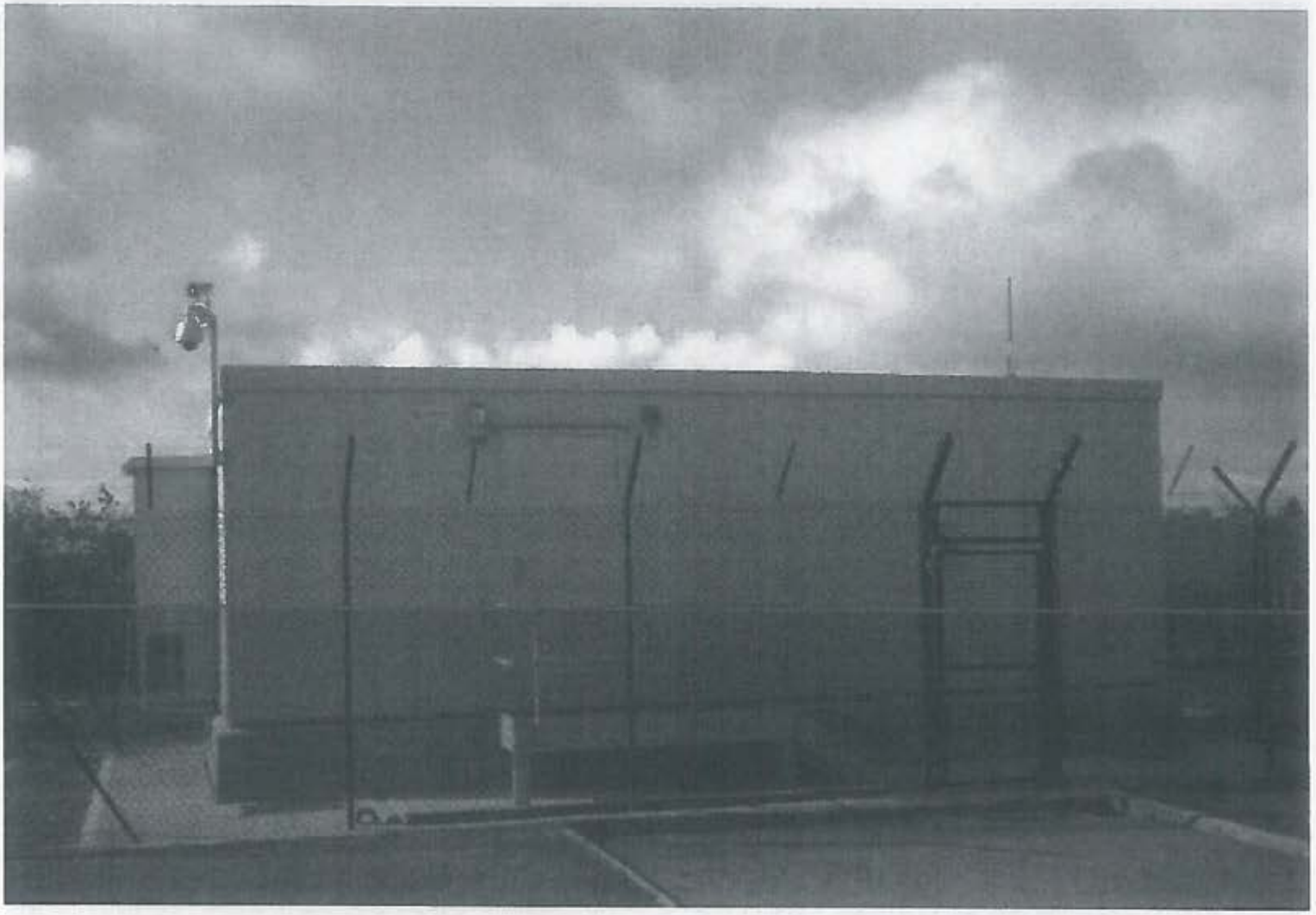
- Wide reach
- Highly secure resilient networks
- Bespoke, custom solutions
- Speed of roll out
- Cost savings
- Scalability

Networks

National Network

- 860km of fibre network linking Dublin (Fully Diverse Connections back to Dublin) and:
  - Galway
  - Ennis
  - Athlone & Mullingar
  - Shannon
  - Limerick
  - Cork
  - Dungarvan
  - New Ross
  - Carlow
  - Blessington
- 165km of network linking Galway and Killala subsea CLS (AEC1)
- 100km of Network to connect to AEC2/ Havfrue Sub Sea CLS by end of 2019
- Existing interconnects with Enet in towns throught the country





Co-Location

The Equipment cabins located at Point of Presence (PoP) sites on the Aurora Telecom National Network have been designed and built to provide customers with as complete a service as possible, with a max spacing of 80km on the network.

- Max spacing of 80kms
- Fully serviced24/7 CMS monitoring
- Infra-red CCTV with interaction speaker
- Air-conditioned to datacentre standard
- High secure sites (Located on GNI Gas Sites 'AGI's')

Aurora
TELECOM

From: [redacted]
To: NRP Mapping
Subject: Submission
Date: 28 September 2019 20:58:38

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Hi , I run a Project Management consultancy Business employing directly and indirectly 26 staff.
We are based in [redacted]
We are in desperate need of Broadband and are only able to achieve 1mb at present.
We therefore rely on a large number of separate individual modems from 3 network which are very expensive.
In order for us to remain in business and give local employment we need good connectivity. We would appreciate
If you could help us with this problem.
Thank you

[redacted]

From: [redacted]
To: NBP Mapping
Subject: NBP - We need broadband please
Date: 30 September 2019 12:16:25

Hi

My eir code is [redacted]

I am writing on behalf of the house holds and agriculture business premises of our area.

We drastically need broadband.

Can you please keep me updated on the NBP so I can pass the information to the people of our area.

Thank you

[redacted]

From: [redacted]
To: NBP Mapping
Subject: NBP Mapping Exercise
Date: 20 September 2019 13:49:33
Attachments: NBP Mapping Consultation - BF.pdf
NBP Submission - Final.pdf

Attention: [redacted]

Dear [redacted]

I attach a submission relating to the Department's NBP mapping exercise. Also attached is a copy of a submission to the Oireachtas Committee to which my submission refers.

Please acknowledge receipt.

Thanks

[redacted]

--

[redacted]

[redacted],

[redacted]
Ireland

Home Tel: [redacted]
Work Tel:
Mobile:

Email: [redacted]

National Broadband Plan – Public Consultation
Department of Communications, Climate Action & Environment
29-31 Adelaide Road
Dublin 2
Ireland
D02 X285

Sent by email to: nbpmapping@dccae.gov.ie
Additional attachment: Submission to Oireachtas Committee

Friday 20th September 2019

NBP – Conclusion of Mapping Exercise for the Intervention Area Pre-Deployment - [redacted]

Dear [redacted],

I wish to make a submission about the NBP mapping exercise on behalf of a near relative and my own account as a tax-paying stakeholder.

Background

My near relative lives in East Clare in a townland that is at least ten kilometres from the nearest Light Blue Area. The townland has 13 premises, is within the NBP IA and isn't covered by operators or planned rural deployment. Internet access was required for personal and professional reasons and, after research, my relative opted for a satellite service provided by Big Blue Broadband. This service which provides about 20 Mbps with a 50 GB priority data allowance has to date been moderately satisfactory albeit with latency problems. In the absence of certainly about gaining access to NBP broadband, it is very probable that my relative will upgrade to a faster satellite service once it becomes available in Ireland.

This experience prompts a basic question about the veracity of the Department's mapping exercise.

For the record, I made a detailed written submission during August last to the Oireachtas Committee on Communications, Climate Action and Environment indicating my concerns about the likely cost of the NBP and urging that consideration be given to the inclusion of next generation satellite and fixed wireless broadband to complement fibre and mobile in order to reduce the NBP's cost and accelerate its delivery. A copy of the submission is attached to this letter.

Based on the NBP's expected cost to the Exchequer of €2.5 billion (net of VAT) and an assumed uptake of 30% for the currently mapped 540,000 premises, the cost per connected premises works out at approximately €15,000. By any measure, this is an extraordinarily large amount given the overall condition of the State's finances.

High-speed Satellite Broadband

Several major companies are developing new and technically-sophisticated, satellite-based broadband services specifically to target vehicles, unserved and underserved premises worldwide. SpaceX, based in the USA, is the most advanced with detailed plans to deploy its Starlink constellation comprising almost twelve thousand low-Earth orbit satellites. To date, it has launched sixty test satellites and plans to launch about 1,700 further satellites before the end of next year. SpaceX will then be a position to start providing high-speed broadband services worldwide, including to rural households in Ireland. Under the terms of its FCC license, SpaceX will launch a further four thousand satellites before end 2024 and an additional six thousand by 2027.

SpaceX is likely to announce preliminary subscription rates, performance levels and other commercial terms by early-mid 2020 as it plans to commence US operations later that year. It has indicated that download speeds will progressively reach one Gbps according as its constellation expands. Based on SpaceX's proposed launch cadence, Starlink is likely to be offering low-cost, high-speed broadband throughout rural Ireland well before the NBP is fully operational.

SpaceX's service which is backed by Google entails an initial investment of about US$10 billion. Prominent competitors and other key players include Amazon, Facebook, Boeing, OneWeb and TelSat. By the mid/late twenties, up to twenty thousand satellites could be delivering high-speed broadband services, with low latency, to rural, semi-rural and remote areas worldwide at speeds comparable with fibre. Currently, no satellites provide such services which are expected to become major components of growth within space and internet-related marketplaces throughout the life of the NBP.

Impact on Intervention Area

Against this background, I submit that the Department should ensure that its mapping exercise takes account of these imminent developments and their potential role in helping to provide Next Generation Access (NGA) in rural Ireland.

These satellite services will require no subsidisation or capital investment by the State but, if ignored, they could provide significant competition to the NBP and lead to the Exchequer being exposed (a) under the proposed NBP contract to substantial costs arising from unanticipated erosion of the intervention area and (b) to a dramatic escalation in the Exchequer's contribution per connected premises.

Reverting to my Oireachtas submission, its key recommendation was "*that independent experts in space and comms technologies be engaged to update the already cited OECD's report on "The Evolving Role of Satellite Networks in Rural and Remote Broadband Access"*

from an Irish perspective along with critical examination of short-medium term plans by satellite broadband service providers and an assessment of their likely impact on Ireland".

It would, in my opinion, be imprudent for the Department to finalise its mapping exercise before undertaking this review which should only take 2-3 months to complete. It would help identify the potential of the proposed satellite services, in conjunction with fibre, mobile and fixed wireless, to provide NGA and meet the EU's objective of providing 100% of households with download speeds of at least 100 Mbps by 2025 and up to one Gbps eventually. On that basis, the Department could accommodate satellite broadband in its mapping exercise and during the actual roll out across the Intervention Area. This would lead to a major reduction in the Exchequer's contribution without compromising the NGA objective.

In closing, I wish to state that I have no relationship with any existing or prospective supplier – this submission is being made solely as a taxpaying stakeholder and on behalf of my rural-based relative.

Yours sincerely

Updated Submission

to

Oireachtas Committee on Communications, Climate Action and Environment

about

National Broadband Plan

This Submission dated 21st July 2019 supersedes that dated 16th June 2019. In addition to minor textual changes throughout, Sections 4 and 5 dealing with satellite broadband have been updated, Section 7 presents expanded proposals for an alternative approach to the NBP and Section 8, a specific recommendation to the Oireachtas Committee

Contents

1. Executive Summary

- This submission proposes that an emerging technology, satellite-based broadband, be considered as an alternative, or complementary, to fibre for the National Broadband Plan (NBP).
- Up to now, use of satellites to deliver internet services has been constrained by the need to deploy geostationary satellites located 35,800 kms above the equator. This results in latency problems (delays) in signal transfers between users and satellites.
- New solutions based on low-earth orbiting satellites operating in large constellations have the potential to eliminate these latency problems and bring high-speed broadband to rural areas worldwide at competitive costs.
- The leading player is SpaceX's Starlink which recently launched 60 test satellites and plans to launch up to ten thousand more on a phased basis by mid-2020s. Other key participants include Amazon and OneWeb.
- Starlink may have enough satellites in orbit to start servicing rural areas in Ireland and much of Europe by 2021.
- Satellite broadband is recognised as having great potential to provide high-quality broadband to rural areas and it could very quickly become a significant disruptor of the NBP's fibre-based solution.
- If expectations are fully, or even partly realised (or even slightly deferred), then satellite broadband could impact radically on current proposals for the NBP in terms of costs, timelines, Exchequer contributions and contracting arrangements.
- This submission recommends an initial independent technology assessment to be followed, if favourable, by a comprehensive review of the current NBP with a view to integrating satellite broadband with fibre and fixed wireless to provide high-speed broadband throughout rural Ireland.

2. Background of Submitter

This submission has been compiled by a private individual who, as a taxpayer, has been concerned about aspects of the NBP. He completely favours the extension of broadband throughout rural Ireland but has concerns about the pre-eminent role of fibre on cost grounds and from a technological perspective. He has no links to any commercial interests discussed in this submission.

He is semi-retired having worked as a management consultant for about four decades. His consulting experience has embraced business planning, operational reviews, financial modelling and strategic planning with start-ups, SMEs, larger businesses and incubators. In addition to consulting, he has operated an internet-based business developing and selling business planning tools to users in about 120 countries.

3. Scope of Submission

This submission considers the potential impact of satellite-based broadband services on current proposals for the NBP and its Exchequer funding.

It has been prepared in connection with Oireachtas Committee on Communications, Climate Action and Environment's hearings on the NBP and its brief "to focus on how best to proceed and the best means in which to roll out rural broadband".

Section 4 discusses the emergence of satellite broadband. Section 5 focuses on Starlink and other advanced satellite services. In Section 6, possible consequences for the NBP are considered. Section 7 and 8 present specific proposals and a specific recommendation to the Oireachtas Committee.

4. Satellite Broadband

4.1. Existing Services

Receipt of internet services via satellite is well established. According to ComReg, there are about four thousand users of such services in Ireland. These services are provided by commercial operators via geostationary satellites orbiting at 35,800 kms about the equator. This altitude enables satellites to appear stationary relative to the earth. Signals are uploaded from earth stations and received directly by users using small external disks pointing towards the satellites' fixed positions.

Charges are quite modest - €100 to purchase the disk and about €40 per month for a domestic service offering 50 GB per month with unmetered off-peak usage. While speed is limited to approximately 25 mbps[1] it is more than adequate for email, browsing, streaming etc. The main drawback is latency, the time required for signals to roundtrip to users. This delay can frustrate real-time interactions, for example audio/video calls and gaming. In addition, services can also be disrupted by rain and related climatic conditions.

4.2. Low-Earth Orbit Satellites

To surmount latency problems, the concept of low-earth orbit (LEO) satellite services is being pursued. This envisages mega-constellations of satellites orbiting as low as 500 kms. While needing much less rocket power to place in orbit, their lives will be shorter (at about 5 years) than that of high orbiters. Also, on account of being in such low orbits they will only be visible to end users for short intervals (like the six minutes per orbit for which the International Space Station at 400 kms can be seen periodically from Ireland).

To provide uninterrupted service, constellations of satellites must provide constant coverage above a given point of the earth. Continuity will be provided by adjacent satellites networking with each other and synching with users on the ground. Perhaps most critically, the latency problem connected with geostationary services will be largely solved as signals will only round trip about one thousand kms instead of seventy thousand.

[1] While download speeds of 25 mbps seem slow compared with the proposed speed range of 150-500 mbps for households serviced by the NBP, it is worth noting that the US Federal Communications Commission suggests that speeds in excess of 25 mbps are only needed for households which might use four devices simultaneously including more than one very high-demand application. It also guides that teleworking/student work and streaming Ultra HD 4k Video need speeds of 5-25 mbps or greater per user. This begs the question as to how in a short number of years, rural households would need bandwidth amounting to, say, ten times more than is currently needed. Obviously, schools, businesses and other organisations are likely to need greater bandwidth.

Several major technology corporations are on record as exploring the possible use of LEO satellites. These included Facebook, Boeing, Amazon, SpaceX, Samsung, Telesat, LeoSat and OneWeb.

To date, OneWeb has launched six LEO satellites (February 2019) and SpaceX has launched sixty (May 2019).

For completeness, it should be mentioned that aside from LEO satellites, atmospheric-based internet services including kites, balloons and drones have been very limited in scope and success to provide internet services in rural areas.

5. Starlink, Kuiper & OneWeb

The three most advanced proposals for satellite broadband - Starlink, Amazon and OneWeb - are discussed below.

5.1. Starlink

SpaceX is a pioneering commercial operator and is perhaps best known for developing reusable rocket stages. Starlink is its LEO program.

Starlink plans to place over ten thousand satellites in orbit within the next five years to provide high-speed, low-cost broadband services to rural, remote and semi-rural communities worldwide. By way of comparison, just ten comms satellites were launched by ten separate rockets in 2016 and only about two thousand satellites are currently operational.

The Federal Communications Commission has estimated that 26% of people in rural areas in the US are not covered by terrestrial broadband services. Only about 10-20% of the Earth's landmass is covered by terrestrial cell towers.

In May this year Starlink placed 60 beta-test satellites (payload of 18.5 tonnes) in orbit at 450 kms using a twice-used Falcon 9 rocket. Designated version 0.9, these satellites lack laser interconnectivity but incorporate many significant features including miniaturisation, single solar sails and solar-powered jets. While ground contact has been lost with three satellites the remainder have propelled themselves into higher orbits at 500 kms for extensive testing with high definition video and high-bandwidth gaming.

This video taken from the Netherlands shows the satellites progressing in 'train' formation shortly after being deployed. It should be said that this has raised concerns amongst astronomers about the adverse impact of thousands of 'lit' satellites on their observation work.

Apparently, SpaceX intends to use profits from Starlink to help fund an expedition to Mars. To date it has raised about US$1.3 billion and is valued at over 33 billion dollars. The current Starlink program is expected to initially cost about US$10 billion. SpaceX is targeting a 3% share of the trillion-dollar global Internet connectivity market. It expects to achieve revenues of about US$30 billion a year once Starlink is fully operational - this contrasts with just US$3 billion a year generated by its more mature rocket and space transport operations.

Naturally, SpaceX is secretive, and insightful updates are often provided by its founder, [redacted] who is also involved with Tesla e-cars and the Boring Company which plans to link major US cities by high-speed, subterranean rail links.

The following has been gleamed from recent press releases and statements:

- The Federal Communications Commission has given SpaceX permission to launch nearly 12,000 Starlink satellites to operate in the Ku-and Ka-band spectrums.
- All going well with initial launches, SpaceX will launch about 60 or more satellites per month into the middle of the next decade.
- Initial operational capability will be reached with 360 satellites. A preliminary service confined to latitudes between the southern half of Canada and Northern half of the US could start in 2021 once about fifteen hundred satellites have been successfully deployed. This service band would embrace Ireland and much of Europe. An initial world-wide service aimed at low and medium population densities could commence once about three thousand satellites are in orbit.
- End users will access Starlink using an externally-mounted phased-array beam-forming antennas about the size and shape of a pizza box. Mounted externally on walls or even vehicles, the antennas are software-driven, contain no moving parts and are not directional. The initial manufacturing cost could be about US$300-500 per unit (as compared with US$100,000 when first developed) and should drop sharply once mass production commences.
- Starlink claims that it will ultimately offer download speeds of up 1 Gbps. It will initially target rural and remote areas on account of the low orbits, limited numbers of satellites, restricted bandwidth per satellite (about 20 gigabits per second, equivalent to four thousand users simultaneously streaming 4K videos) and service radius per satellite of several thousand kilometres.
- Performances, technologies and services will improve as new generations of satellites are launched, about every five years, into both low- and medium-earth orbits.
- Starlink satellites incorporate collision avoidance mechanisms and will be capable of being deorbited remotely.

Although somewhat US-centric, this introductory statement by the VP Satellite Government Affairs at SpaceX before the US Senate Committee on Commerce, Science and Technology on May 3rd 2017 describes the objectives and plans for Starlink. These now seem to be coming to fruition and are very relevant to the Oireachtas Committee's quest for the "best means in which to roll out rural broadband".

Overall, Starlink appears to have a huge head start on its competitors.

5.2. Kuiper

In April 2019 Amazon announced that its Project Kuiper (no web presence) would enter the internet satellite business and in July 2019 it filed an application with the FCC to put 3,236 satellites, operating in the Ka frequency band, into low earth orbit to target the four billion people in the world without broadband connections.

The proposed service with be confined to mid-latitudes with the satellites grouped in 98 different orbital planes and into two orbital shells at 590 km and 630 km.

Amazon expects, all going well, that it will offer services, sometime in the next few years, once it its first group of 578 satellites are in working orbits.

Little information is available on the design of Kuiper's satellites which will have a 10 year like and even less is known about its launch plans. However, it should be noted that Jeff Bezos (CEO and founder of Amazon) is developing the New Shepard reusable rocket through his Blue Origin space transport company.

5.3. OneWeb

UK-based OneWeb is backed by [redacted] It has raised US$3.4 billion in pursuit of its objective to become a global communications business utilising LEO satellites. It aims to provide internet services to rural and remote places as well as to a range of markets including aero, maritime, land mobility and cellular backhaul. Its plans call for an initial constellation of 648 satellites with 600 active with 48 on-orbit spares orbiting at1,200 kms in 12 planes. The number could grow to 1,980.

OneWeb has contracted Airbus to construct its satellites and has entered into launch deals with Virgin Galactic and Arianespace..

On February 27, 2019, OneWeb successfully launched its first six satellite into low-earth orbit From French Guiana using a Russian Suyez rocket. Initial testing in 'ideal' conditions has been very promising with a top data speed of up to 400 mbps and a latency time averaging 32 milliseconds being reported.

OneWeb plans to launch 30 satellites per month starting in late 2019. It expects to deliver a partial service in 2020 and a fully functioning commercial one in 2021. One senses provision of rural broadband may not be highest priority for OneWeb.

6. Consequences for NBP

6.1. The Past

The NBP was conceived back in 2012 as a limited fibre-based rural broadband service. Since then, it mushroomed into an all-compassing universal service costing about €5 billion to develop. The plan will have a life of at least 25 years and envisages that fibre will be laid to pass 540,000 rural premises by 2027.

NBP planners have remained wedded to the original fibre-based solution throughout this time although consideration was given to 4G/5G mobile as an alternative solution as per a report "FTTP or 4G/5G for Ireland's NBP?" dated 5th December 2018 and published by the Department of Communications, Climate Action and Environment (DCCAE) along with other background documents in May 2019.

No consideration appears to have been given by NBP planners to satellite broadband. In its press release dated 7th May 2019, the DCCAE referenced the need for future proofing based on the EC's strategy for "Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society". This document, published back in September 2016, made no reference to satellite broadband. Also referenced in the same press release was a ComReg report entitled "Meeting Consumers' Connectivity Needs". Dated November 2018, this report made a single reference (page 53) to last-generation satellite networks which are currently available in Ireland albeit with restricted performances.

Meantime, in February 2018 the OECD published "Bridging the Rural Digital Divide" which recognised satellites as "a key technology for providing rural and remote broadband access". This referenced an earlier OECD technical report entitled "The Evolving Role of Satellite Networks in Rural and Remote Broadband Access". Although published back in December 2016, and in need of a major update, it delved into the potentially significant roles of low- and middle-earth orbit satellites and referenced several proposed systems including SpaceX's Starlink.

It seems as if NBP planners may have been locked into a fibre solution for so long and so deeply that they have not considered the emerging new satellite-based alternatives either standalone or complementary to a fibre-based network. In fairness to these planners, the proposed NBP technology has been supplier driven and clarity about the potential of satellite broadband is a recent development, and certainly wouldn't have been high on anyone's agenda back in 2012 or even in 2016.

6.2. The Future

Whilst it is very early days for satellite broadband, the pace of development is undoubtedly accelerating and could be massive over the next 3-5 years at the very same time that the NBP is laying out its fibre network and incurring major fixed costs.

In judging the future, it is important to bear in mind the impact of Moore's law on microprocessor power on satellite technologies and that new generations of mobile technology seem to appear every ten years (roughly). At the same time, it is essential to avoid excessive overreliance on any single new technology as some new technologies and solutions get over-hyped, disappear without trace and are overtaken by newer, better technologies.

For discussion purposes, here are two diametrically opposite and extreme views of satellite broadband from the NBP's perspective:

1. Starlink and its competitors are successful in delivering world-wide broadband on time, to the required performance standards and at a modest price to users. If adopted in Ireland, its service would require no funding by Irish taxpayers; would offer all the benefits, without the costs, as set out in the NBP cost/benefit analyses; would be deliverable without any Irish intervention or Exchequer funding; and would become a competitive and disruptive alternative to the NBP's service.
2. Starlink and its alternatives run into major technical problems, their fund-raising is disrupted; performances are inferior and major delays in offering services are encountered leading to considerable doubt and uncertainty about satellite broadband.

The middle-ground view might be that full-scale satellite services would become available, with acceptable performances and pricing somewhat more slowly than expected, and that their progress demonstrates the potential to provide full-scale services inside the next decade.

Set against that view are the facts that the current NBP is one of the biggest capital projects ever undertaken in the State (costing over half the expected total cost of the Starlink program); is widely accepted as entailing considerable financial and operational risk; requires a net injection of €2.5 billion by the State in addition to substantial private funding; and entails a multi-year construction phase.

During the NBP's 25+ year operational phase, microprocessors for digital signal processing are likely to increase performance by a factor of thousand and mobile tech could be into its G7

generation. This technological progression could pose major challenges to fixed fibre services as has already happened in the case of traditional telephone lines, fax etc.

7. Proposals

7.1. Tech Study

Based on the foregoing assessments and bearing in mind that the NBP has been evolving for seven years, there is a compelling case for the Government to undertake an independent technical review of the potential of satellite broadband before committing to an entirely fibre-based NBP for the next three decades.

At worst, this review might delay implementation of the current NBP by several months and, at best, it would lead to the NBP's underlying objectives being achieved at a much lower Exchequer cost and in line with or even ahead of existing timelines.

Our central proposal is that independent experts in space and comms technologies be engaged to update the already cited OECD's report on "The Evolving Role of Satellite Networks in Rural and Remote Broadband Access" from an Irish perspective along with critical examination of short-medium term plans by satellite broadband service providers and an assessment of their likely impact on Ireland.

Other specific proposals are as follows:

1. For completeness and to avoid excluding any alternatives to satellite, an independent study should be undertaken to assess the potential of advanced Fixed Wireless Access (FWA) delivered by regional Wireless Internet Service Providers to provide high-performance rural broadband services at moderate costs. This work could use the Regional Internet Service Providers' submission to the Oireachtas Committee as a starting point and should involve consultation with ComReg and the DCCAE as regards spectrum allocations. This would help clarify the extent to which satellite broadband and FWA would be complementary or competing within the Intervention Area.
2. It would be beneficial for key agencies involved in the NBP to tap in local satellite-related expertise including the Space Enterprise Coordination Group being formed under the auspices of the Department of Business, Enterprise and Innovation; National Space Centre (independent teleport operator near Midleton, Co Cork); Arralis (developer of beam steering antennas based in Limerick); and space-related technology departments within higher education and research institutes.
3. In parallel with the external studies, relevant departments and agencies should closely monitor fast-moving developments in satellite broadband. And, State agencies like IDA should be vigilant to employment opportunities arising from the need to mass produce thousands of highly complex satellites every year and for satellite earth gateways that would benefit from proximity to data centres in Ireland.

7.2. Looking Ahead

In theory and *in extremis*, it would be possible to suspend the entire NBP until satellite broadband becomes fully commercial at moderate costs and with proven performances. Exchequer support might be limited to, say, subsidisation, at a cost of tens of millions, of user

antennae to incentivise uptake. This approach would be very high risk and politically, economically and socially unacceptable even though the Benefit/Cost ratio would be almost infinite.

More realistically and assuming a relatively positive outcome from the technology study, a practical next step could involve the design of a multi-tech approach embracing fibre, satellite, wireless and 4G/5G technologies. It is possible to envisage that this would offer the NBP's full benefits while dramatically scaling back timelines, and altering roll-out strategies and timing, costs, contractual arrangements, structures and Exchequer funding/ownership as summarised in the table below. This should also include a *value-for-money* review of so-called "red lines", e.g. coverage, speed, service levels with a view to securing greater flexibility and realism having regard to demand/needs and limited funding.

Phase	Intervention Areas	Main Technologies (Possible Order of Importance)[2]	Premises Passed	Exchequer Contribution	Key Orgs	Timing Years
1[1]	300 broadband connection points (BCP/PoPs)	Fibre	N/A	Modest[4]	Public	1-2
2[1]	Additional 1,000 BCP/PoPs	Fibre	N/A	Modest[4]	Public	2-3
2	Less remote	Fibre/Fixed Wireless/Satellite	c.270k[3]	Moderate[5]	Public/ Private	2-3[6]
3	Most remote	Satellite/Fixed Wireless/Mobile	c.270k	Minimal[5]	Private	3-5

1. These phases could be State funded/owned and accessible to private broadband service providers on a concession basis for building out using fibre and/or fixed wireless.
2. Final order of importance would be based on geography and cost, performance and technical progress by fixed wireless and satellite broadband.
3. Takes no account of premises within the intervention area already receiving, or potentially getting, broadband via fixed wireless from regional ISPs or fibre through national operators. ComReg has estimated that many of the 47k premises currently using fixed wireless are located in rural areas.
4. Based on the cost estimate of less than one hundred million euro for "Plan Z" developed by the DCCAE and DPER to provide fibre to 1,800 key sites for an initial five years – see appendix to Briefing on the National Broadband Plan for Meeting with Minister Bruton dated 21st February 2019.
5. For details about proposals for Exchequer support towards the expansion of Fixed Wireless Access broadband services, see submission to the Oireachtas Committee by the Regional Internet Service Providers Association.
   In the case of satellite, an Exchequer contribution towards the initial high cost of antennae of €200 per user might cost the Exchequer a once-off twenty million euro if, say, a hundred thousand users opt for satellite broadband.
6. Assumes that commercial satellite broadband becomes available in Ireland by early/mid-twenties.

This approach opens up additional options to complement those explored in a detailed paper entitled Contingency Plan Options 2019 prepared by the DCCAE following discussions with the DPER. This considered three "Plan B" options as follows:

- A phased approach to the provision of fibre services based on experiences in two selected deployment areas.
- Separate build and operate contracts within a €1 billion budget.
- Subsidised rollout of fibre to multiple locations in order to provide backhaul facilities for commercial operators who would deliver broadband locally.

Plan B did not consider satellite broadband and almost all financial and related data was heavily redacted in the published version.

8. Recommendation and Conclusion

In summary, this submission proposes the immediate build-out of fibre to about 1,300 broadband connection points. This would be followed by the provision of further fibre for additional connectivity and backhaul alongside the deployment of emerging satellite and fixed wireless broadband technologies to service individual premises. The objective would be to achieve maximum rural coverage to an optimal standard and at a moderate cost to the Exchequer.

Given that the NBP has been in gestation for several years, that over €20 million has been expended to date and that execution could cost the Exchequer well over €2 billion, the Oireachtas Committee is urged to recommend a modest delay and limited investment to facilitate independent, detailed assessment of the proposals in this submission.

Rural Ireland needs, arguably even more than urban Ireland, access to the benefits of high-quality broadband services. Hopefully, this submission contributes to this objective and offers a more cost-effective "means in which to roll out rural broadband".

Initial submission dated 16th June 2019 and revised 21st July 2019

NBP Mapping Submission

Prepared by:

[redacted]

30th Sept 2019

V2.2-public

TABLE OF CONTENTS

1 INTRODUCTION TO BBNET

BBnet is a registered trading name of EOBO Ltd and is a connectivity provider of FWA internet services as well as a wholesale partner with OpenEir, enet providing FTTx services. Our clients are both national and international.

***** CONFIDENTIAL INFORMATION REMOVED *****

Founded in 2005, BBnet provide various connectivity and resilient connectivity solutions as well as VoIP, Hosted PBX and IPTV for our residential and business clients.

We are headquartered in [redacted] and use a combination of Tier 1 fibre backhaul, licenced radio links and license exempt spectrum to deliver our high-quality internet services to our growing customer base. BBnet has over 75 trans mission sites located across Ireland. BBnet is registered with Comreg and Ireland's Data Protection Commissioner and is also a member of the Regional Internet Service Providers Association (RISPA) and of the internet registry, RIPE.

BBnet is currently an approved vendor under the Primary Schools Broadband Framework and the Office of Government Framework for the provision of Wide Area Network connectivity services.

BBnet are also interconnected with Tier 1 fibre and backhaul operators in Ireland, thus giving us complete national presence over Fibre, Wireless and Copper based networks with offers from 10Mb to 10Gbps.

2 Current Network Implementation

***** CONFIDENTIAL INFORMATION REMOVED *****

2.1. Internet Facing Connectivity (External)

BBnet's 'External' network is our Internet facing network based in [redacted] where we terminate most of our national fibre circuits.

Our Upstream Providers in Equinix Kilcarbery are:

- Cogent - Primary & Secondary
- GTT (previously Hibernia) - Primary & Secondary
- INEX LAN1 & LAN2

Each Upstream provider are terminated on our routers using dual presentation on independent hardware with downstream occurring via in-cabinet patch or multiple national fibre across our core network delivery layer-2 connectivity to our various points of handover (POH).

Interconnectivity between our External facing routers and downstream facing routers is via an iBGP mesh topology.

The network has been designed for delivery of high availability.

2.2. Core Network

Our Core is heavily dependent on Fibre and we then use high capacity FDD Links to transfer bandwidth from a fibre POH to high sites.

Our national core fibre network comprises of multi-gigabit Fibre networks delivery to POH locations. Licenced wireless technologies are then deployed from POH to further connect high sites to our national fibre network.

BBnet's core has been designed around using quality fibre providers with an SLA that is appropriate for Enterprise, Government & Residential applications.

Our core network spans across multiple datacentres nationally & internationally

- Equinix DB2, Dublin, Telehouse 1
  - Tier 1 IP Providers:
    - Cogent Primary & Secondary
    - GTT Primary & Secondary
    - INEX LAN 1 & 2
  - Interconnects:
    - Enet
    - OpenEir
    - BT
    - ESBT
    - Viatel
    - Host Ireland
    - PermNET
    - INEX
    - Cogent
    - GTT
    - Irish Telecom (Paradyn)

        - IMS
- Westpark Business Campus, Shannon
    - Interconnects:
        - Enet
        - OpenEir
        - BT
- Interxion, Dublin
    - Interconnects:
        - INEX LAN1 & LAN2
        - HEAnet
- Cork Internet Exchange (CIX), Cork
    - Tier 1 IP Providers:
        - CIX
    - Interconnects:
        - Enet
        - CIX
- International PoP's in London, New York, Barbados

2.3. Backhaul Network

Our backhaul networks interconnect our various key high sites into our Fibre POH locations using high capacity Ethernet radio links. We have designed the radio links with adequate fade margins to achieve 99.9% availability where feasible.

Redundant paths between high sites are also implemented allowing for hardware and fibre resiliency in the case of fibre breaks/maintenance.

BBnet use a range of licenced & licence-exempt microwave radio links for connectivity between POH to various high sites.

- SIAE Microelettronica ALFOplus2
    - Licenced bands 6-42GHz
    - Up to 2+0 XPIC
    - Up to 2Gbps FDX capacity
    - "ALFOplus2 Datasheet.pdf"
- SIAE Microelettronica ALFOplus
    - Licenced bands 6-42GHz
    - Licence-exempt bands 17 & 24GHz
    - Up to 500Mbps FDX capacity
    - "ALFOplus Datasheet.pdf"
- SIAE Microelettronica ALFOplus80HD
    - Licenced E-Band 80GHz
    - Up to 2Gbps FDX
    - "ALFOplus80HD Datasheet.pdf"
- SIAE Microelettronica ALFOplus80HDx
    - Licenced E-Band 80GHz
    - Up to 10Gbps FDX
    - "ALFOplus80HDx Datasheet.pdf"
- Racom Ray2 17GHz 360Mbps FDX FDD Radio Link
    - https://www.racom.eu/download/hw/ray/free/eng/00_letaky/ray-dsA4-en.pdf

2.4. Access Layer Network

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.

2.4.1. Access Layer Network

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.

RADWIN 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 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.

2.4.2. Subscriber Units

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

2.4.3. Datasheets

- RADWIN SU-AIR 100 Series
  - PDF Datasheet "RW-5H00-2A54.pdf"
- 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_qZrqY_0

2.4.4. Noise Mitigation Technology

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:

- Smart BEAMFORMING & BEAMSTEERING (2nd Gen)
- Network Synchronisation (GPS) (TDD sync)
- 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)
- Dynamic Channel Bandwidth Allocation (D-CBA)

2.5. Backhaul Capacity Management & Planning

BBnet NOC is based in Shannon, Co. Clare where our Customer & Networks Support teams are constantly monitoring our network performances. We use a combination of software with triggered SLA alerts setup on various parameters. Some NMS systems in operation are:

- ISPAdmin
- RADWIN WinNMS
- Weathermap
- Smoke Ping
- Nagios
- Papertrail
- Uptime Robot
- Xymon

Weathermap is a Network Visualisation Tool which reports Network Statistics allowing proactive capacity planning. Once links reach a set threshold capacity as reported by Weathermap, BBnet network engineers are tasked to plan an upgrade for increased bandwidth.

Further information is available on request.

3 Network Growth

3.1. Core Network

***** CONFIDENTIAL INFORMATION REMOVED *****

3.2. Planned NGA Services Growth

BBnet will continue organic growth of its NGA network and will continue to upgrade backhaul as necessary by implementing a continuous improvement programme on non-NGA BBnet coverage spots. BBnet is also constantly identifying new coverage areas.

However, along with a list of what we consider the 36,197 NGA Eircodes, we will also submit a list of all 59,994 Eircodes currently covered by our network, which for very little capital outlay will be 100% converted to what we consider NGA spec by Q4 2021. This is part of our self-financed upgrade route which has already been budgeted for internally.

We are however unable to furnish the department with this information due to the detailed information requested and limited timescale.

4 Coverage data as illustrated in the form of Polygonised Data set

4.1. Table of Location of Base stations

***** CONFIDENTIAL INFORMATION REMOVED *****

4.2. Table of Location of Connected Clients

We are unable to provide a full data set as requested as a number of our clients are connected from prior to the release of Eircodes. The amount of work necessary to acquire this information is more than the time allowed for this submission.

We have supplied shapefiles as requested which can be used to view the relevant coverage area.

Our connected clients will be included within these shapefiles & Eircodes covered files submitted.

Dropbox link for shapefiles:

[redacted]

4.3. Table of Location of Premises Passed based on High Resolution LIDAR and DSM data

Eircode data file submitted as an attachment to our e-mail in CSV format: "BBNet_NGA_Detail.csv"

Shapefiles due to the size are available using the following Dropbox link:

[redacted]

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

5.1. WIRELESSCOVERAGE.COM 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 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.

5.2. WIRELESSCOVERAGE.COM METHOD

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 minimum 30Mbps download & 6Mbps upload.

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

- All Sites from our ISP at NGA
- 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.

5.3. NGA ASSUMPTIONS

BBnet use RADWIN for the provision of its FWA NGA services across it's access layer network as described above.

Table: Typical RADWIN JET Base Station with a required throughput of 100Mbps per subscriber unit

Band	5.4 ETSI	
Channel Bandwidth	40 MHz	
Propagation Model	Free Space	
	HBS	HSU
Max TX Power	25 dBm	21 dBm
Antenna Gain	20 dBi	23 dBi
Regulation Limits	EIRP up to 30 dBm	
Required Throughput	100 (Mb/s)	

Table: RADWIN JET Throughput table vs Distance

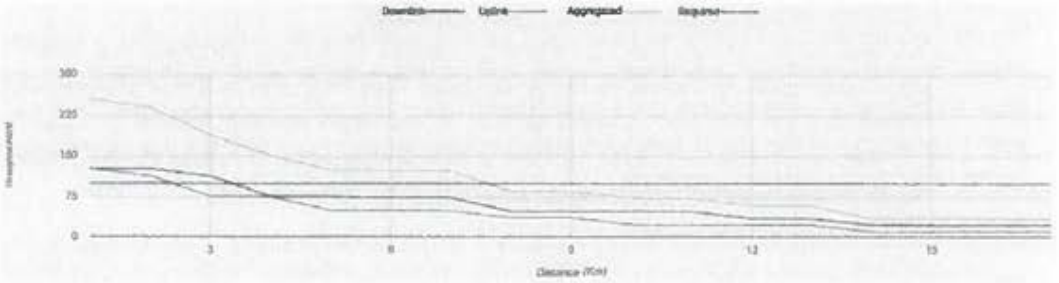


Table: RADWIN JET Distance, RSSI, Aggregated throughput per subscriber, Air rate (MCS)

Distance (Km)	Receive Signal (dBm)		Throughput (Mb/s)			Air Rate (MCS)	
	Downlink	Uplink	Downlink	Uplink	Aggregated	Downlink	Uplink
1	-57	-60	127.7	127.7	255.4	2 x 64-QAM 0.83 (300 Mb/s)	2 x 64-QAM 0.83 (300 Mb/s)
2	-63	-66	126.7	113.8	240.5	2 x 64-QAM 0.83 (300 Mb/s)	2 x 64-QAM 0.75 (270 Mb/s)
3	-67	-70	113.8	76.1	189.9	2 x 64-QAM 0.75 (270 Mb/s)	2 x 16-QAM 0.75 (180 Mb/s)
4	-69	-72	75.5	75.5	151	2 x 16-QAM 0.75 (180 Mb/s)	2 x 16-QAM 0.75 (180 Mb/s)
5	-71	-74	75	50.1	125.1	2 x 16-QAM 0.75 (180 Mb/s)	2 x 16-QAM 0.5 (120 Mb/s)
6	-73	-76	74.4	49.7	124.1	2 x 16-QAM 0.75 (180 Mb/s)	2 x 16-QAM 0.5 (120 Mb/s)
7	-74	-77	73.8	49.3	123.1	2 x 16-QAM 0.75 (180 Mb/s)	2 x 16-QAM 0.5 (120 Mb/s)
8	-75	-78	48.9	36.5	85.4	2 x 16-QAM 0.5 (120 Mb/s)	2 x QPSK 0.75 (90 Mb/s)
9	-76	-79	48.9	36.5	85.4	2 x 16-QAM 0.5 (120 Mb/s)	2 x QPSK 0.75 (90 Mb/s)
10	-77	-80	48.6	24.4	73	2 x 16-QAM 0.5 (120 Mb/s)	2 x QPSK 0.5 (60 Mb/s)
11	-78	-81	48.2	24.2	72.4	2 x 16-QAM 0.5 (120 Mb/s)	2 x QPSK 0.5 (60 Mb/s)
12	-79	-82	35.6	24	59.6	2 x QPSK 0.75 (90 Mb/s)	2 x QPSK 0.5 (60 Mb/s)
13	-79	-82	35.3	23.9	59.2	2 x QPSK 0.75 (90 Mb/s)	2 x QPSK 0.5 (60 Mb/s)
14	-80	-83	23.7	11.7	35.4	2 x QPSK 0.5 (60 Mb/s)	2 x BPSK 0.5 (30 Mb/s)
15	-81	-84	23.7	11.7	35.4	2 x QPSK 0.5 (60 Mb/s)	2 x BPSK 0.5 (30 Mb/s)
16	-81	-84	23.5	11.6	35.1	2 x QPSK 0.5 (60 Mb/s)	2 x BPSK 0.5 (30 Mb/s)
17	-82	-85	23.3	11.5	34.8	2 x QPSK 0.5 (60 Mb/s)	2 x BPSK 0.5 (30 Mb/s)

5.4. 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 in theory that potential obstructions to the wireless signal path calculations were missed. Based upon the algorithm-driven model developed by WIDSM for error calculation, we estimate an error rate of <2% over-statement.

Since the high-resolution data was produced between 2015 and 2017, it is likely that a small amount of unmanaged tree growth has occurred and that new building works will have taken place in the intervening period, which means that a small number of wireless paths may have developed obstructions that reduce their performance and in extremely rare instances, may be blocked. Based upon the algorithm-driven model developed by WIDSM for error calculation, 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. 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. Based upon assumptions derived from previous mapping exercises and benchmarked against WIDSM's model, 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 allow 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 <10%, but it is highly dependent on the technology used by the operator.

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

5.5. 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.

5.6. LIDAR DSM Data Source Coverage According To wirelesscoverage.com

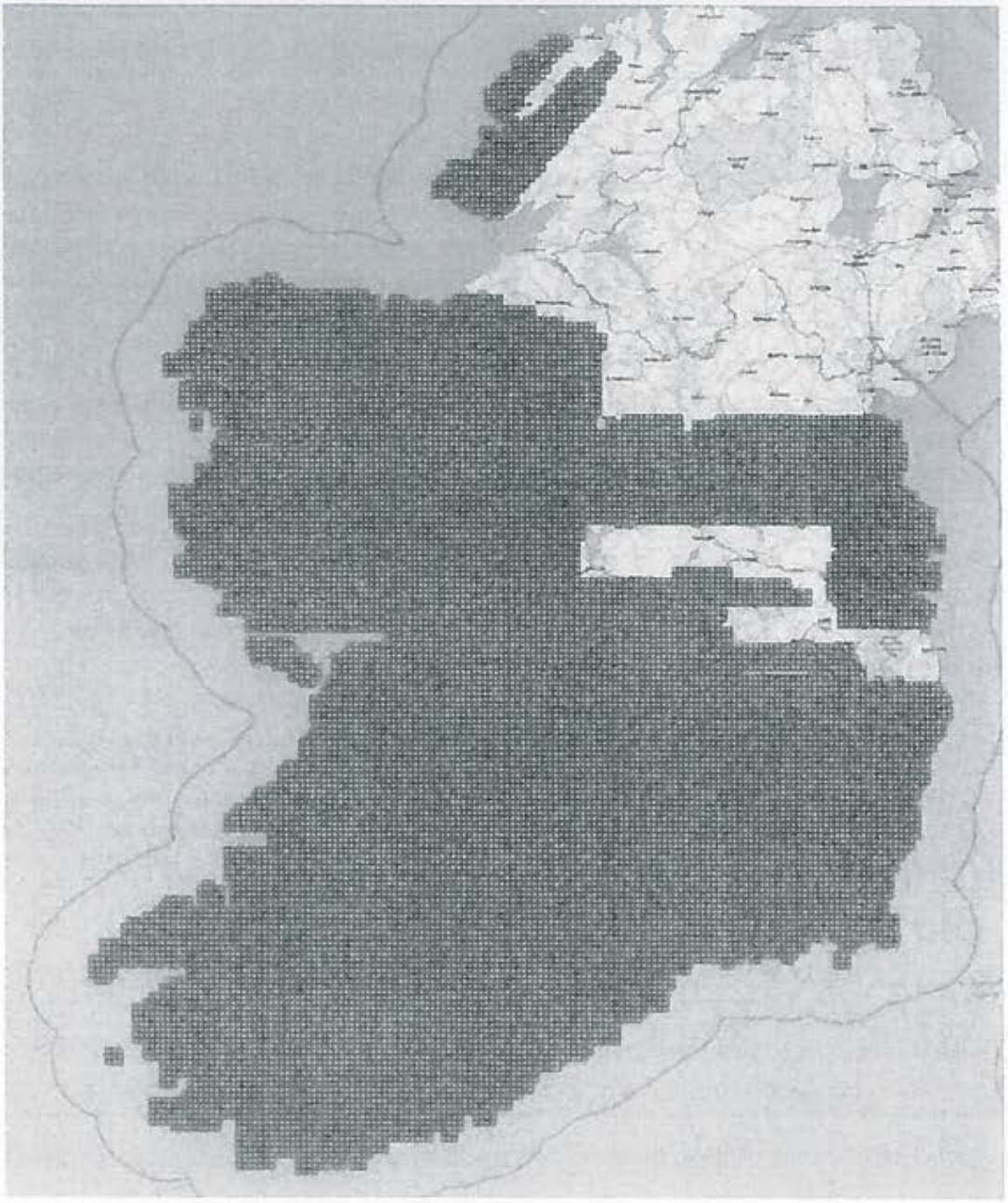


Figure 1. Map of 1m DSM Data from Bluesky International, collected between 2015 and 2017

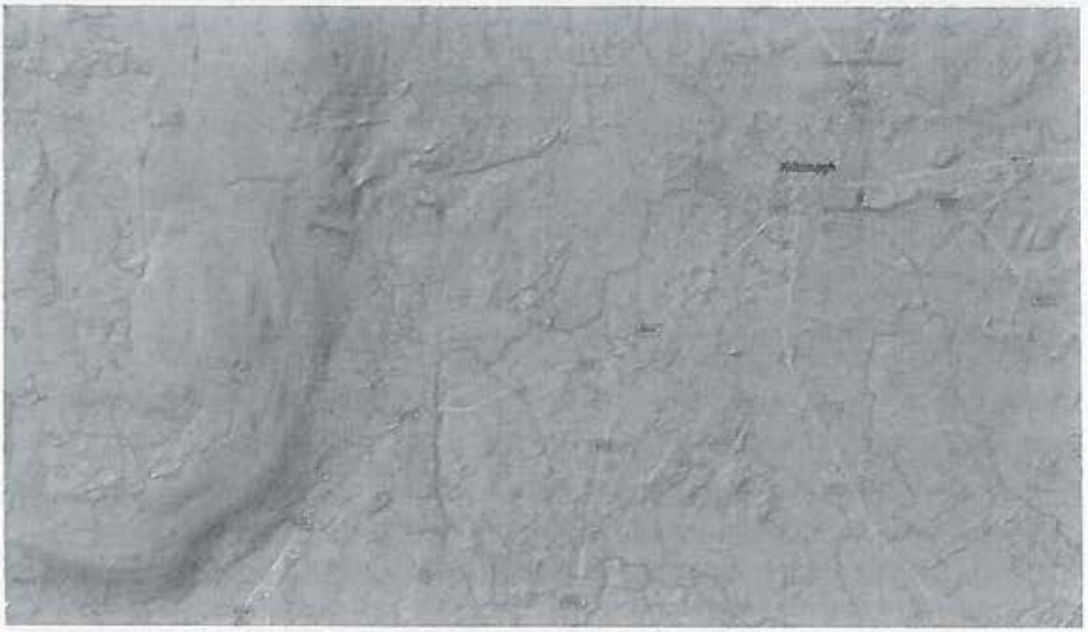


Figure 2. Example render of DSM Data showing trees, buildings and other surface features.

6 WIRELESSCOVERAGE.COM WISDM™ LINE OF SIGHT ENGINE

6.1. 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.

6.2. 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:

- **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.

- **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.

- **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.

- **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.

- **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.

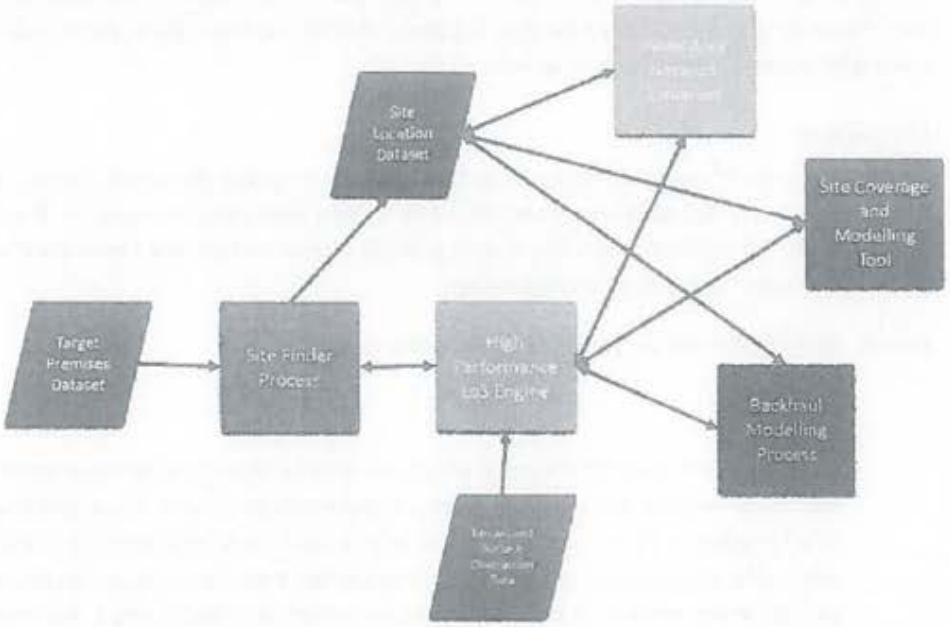


FIGURE 1 WISDM SCHEMATIC SYSTEM OVERVIEW

6.3. 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 Co-ords:	52.721996, -8.735649
Point B Co-ords:	52.747408, -8.789033
Height of A:	10 m
Height of B:	6 m
Tx Power:	13 dBm
Ant Gain A:	20 dBm
Ant Gain B:	22 dBm
RF Frequency:	5740 GHz

Estimated RSSi:	-70 dBm
Azimuth from A:	308 degrees
Azimuth from B:	128 degrees
Elevation from A:	-3.24 degrees
Elevation from B:	3.24 degrees
Link distance:	4.8 km

FIGURE 2 SAMPLE LOS ENGINE INPUT AND OUTPUT

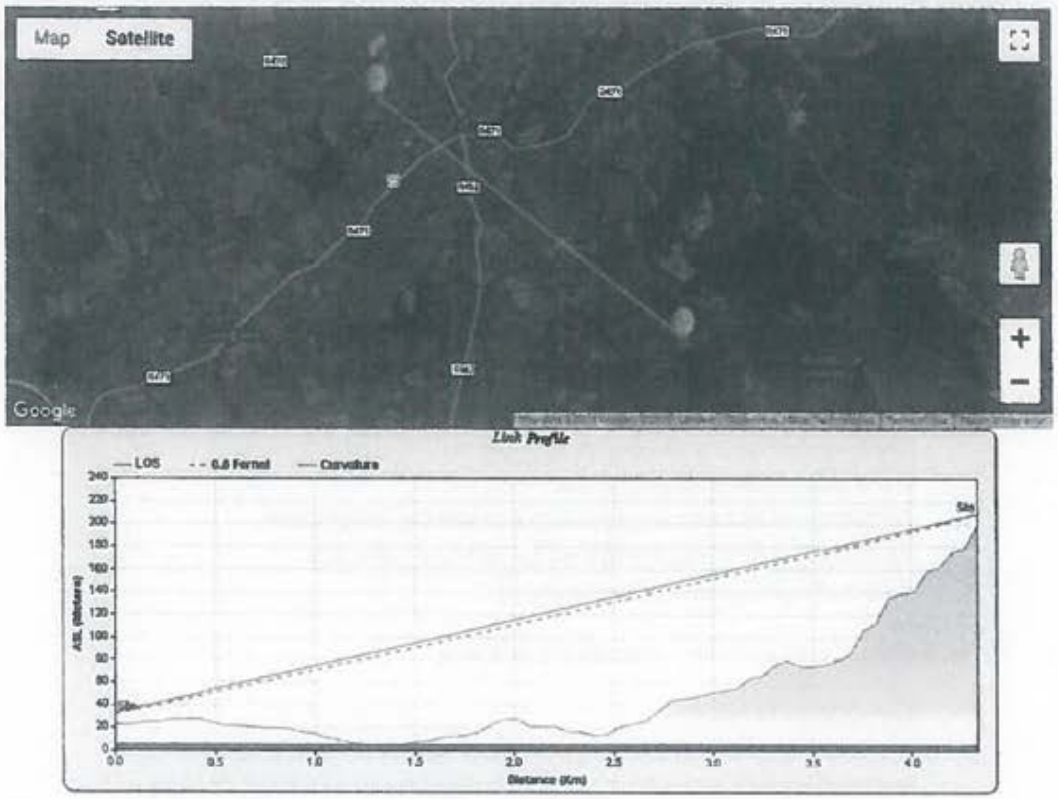


FIGURE 3 SAMPLE LOS GROUND PROFILE IMAGE

6.4. 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; 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:

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

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.

6 Deployment Information

Refer to Section 3.2. Data not being submitted for consideration due to time limitation.

7 Financial Information

Refer to Section 3.2. Data not being submitted for consideration due to time limitation.

8 Conclusion

We hope that the information supplied is constructive and useful.

BBnet have been a backbone of rural Internet connectivity in Ireland since the early 2000's, and many thousands of loyal homes, businesses, multi-nationals, schools & government buildings rely upon our services for their day to day applications. We pride ourselves on local-based Customer & Technical Support.

However, along with a list of what we consider the 36,197 NGA Eircodes, we will also submit a list of all 59,994 Eircodes currently covered by our network, which for very little capital outlay will be 100% converted to what we consider NGA spec by Q4 2021. This is part of our self-financed upgrade route which has already been budgeted for internally.