QMUL Spectrum Sandbox

Spectrum Policy Forum

January 14, 2025

Project Overview

"To trial and demonstrate "proof-of-concept" of dynamic licensing for use of spectrum licensed to mobile operators in under-utilised areas"
– our Spectrum Sandbox Tender, Feb 2024

We applaud Ofcom's local licensing approach, but practicalities prevent the benefits from being realised:

- **Local Access Licence (LAL)** applications take >1 year – this is not commercially viable (we tried!).
- **Shared Access Licence (SAL)** applications are cumbersome (1 per device!) and take weeks/months.

We are examining **Dynamic Licensed Spectrum Allocation**, where ongoing short-term 'leases' – within the bounds of a 'traditional' licence – permit the use of spectrum while avoiding primary users in real-time:

- Enables the use of under-utilised frequencies/areas in (e.g.) **Band 3** (1800MHz) without causing interference to current <u>or evolving</u> MNO usage – unlocking a £million market opportunity for new entrants such as Telet;
- Enables short-term-short-notice and/or bulk use of "upper" **Band n77** (3.8–4.2GHz) – unlocking Content Production usage for broadcasters, and wider and/or event-based deployments for new entrants;
- Implements Ofcom's recent SAL synchronisation concepts to improve density.

Dynamic Licensed Spectrum Allocation

Step 1: Ofcom issues a DSAL or DLAL licence, permitting the operator to run a network (e.g.) "anywhere in Bath in Band 3", but they may not transmit until:

Step 2: Operator's base-stations each make an automatic daily request to a **DSA Server**, specifying their location etc. – only within the bounds of the licence

Step 3: DSA Server automatically determines which frequencies can be used without causing harmful interference – using Ofcom methodologies and data on other licensees)

Step 4: Base-stations are now permitted to transmit as directed by the DSA Server

Step 5: Base-stations report to the DSA Server their **measurements**, and/or their UEs' measurements, of spectrum usage throughout their band

Step 6: If the DSA Server identifies a change in MNO coverage (which must be protected!), it will instruct all relevant DLAL base-stations to change frequency ("Coordinated Detect & Avoid")

Step 7: Base-stations check with the DSA Server every 5 minutes, and will **immediately change frequency** if instructed to

Introduction to the three work packages (WPs)

	Objective of work package	Summary of tasks
WP1 Measurements	Prototype DSA solution In-field measurements	• Design and prototype a database-spectrum sharing solution to facilitate real-time DSA access to LAL and SAL spectrum • Undertake measurements of current usage of mobile spectrum (Band 3) and interference between multiple shared access base stations (Band n77) for use in **WP2**
WP2 Simulations	Simulations and modelling to extend the applicability of the measurements in **WP1**	• Develop detailed simulation of radio environment for rural and urban • Use physical measurements from **WP1** to validate simulations • Assess performance of spectrum sharing under varied conditions • Identify availability of mobile spectrum for new users across the UK for use in **WP3**
WP3 Economics	Analysis of economic benefits and costs	• Identification of DSA use cases and benefits (for LALs and SALs) • Develop spectrum demand scenarios based on spectrum availability from **WP2** • Identify and quantify associated direct benefits and costs • Assessment of wider impacts • Understand regulatory changes required to implement DSA solution

Workshops to engage with stakeholders – first held 11 June 2024

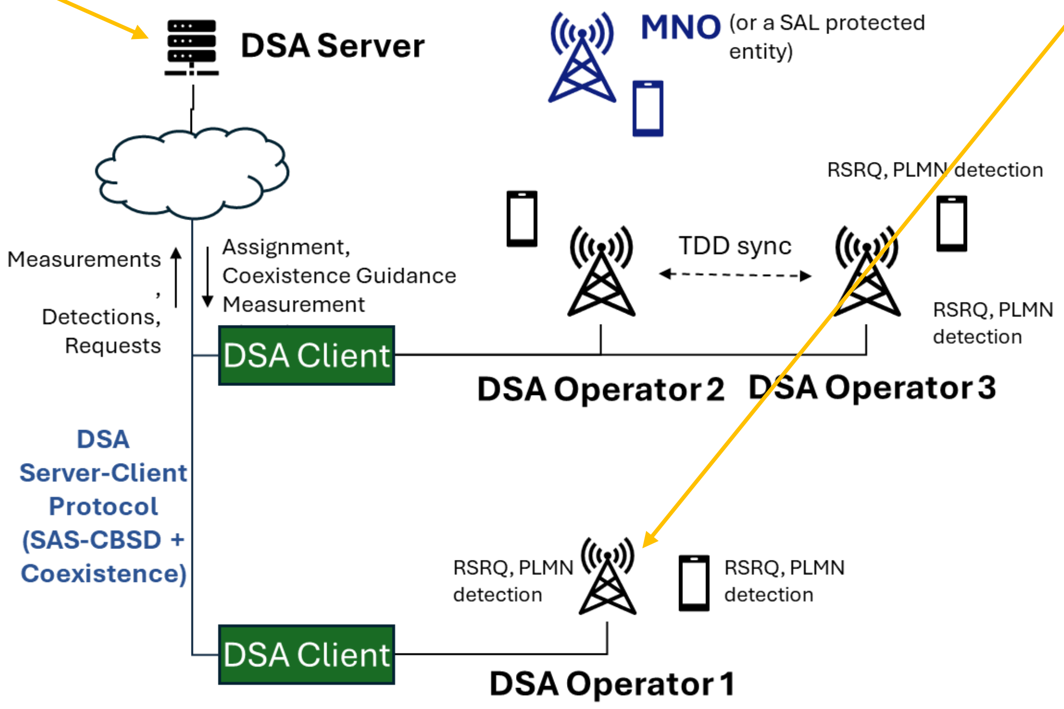
WP1: Prototype DSA system

Software

- Working prototype of DSA Server deployed in cloud
- Implements Ofcom's SAL methodology, and custom basic LAL methodology
- Imports data from Ofcom
- API supports protocol for device-server communication across different rulesets (DSAL, DLAL, etc.)
- Builds on DCMS-funded 5G New Thinking project

Hardware

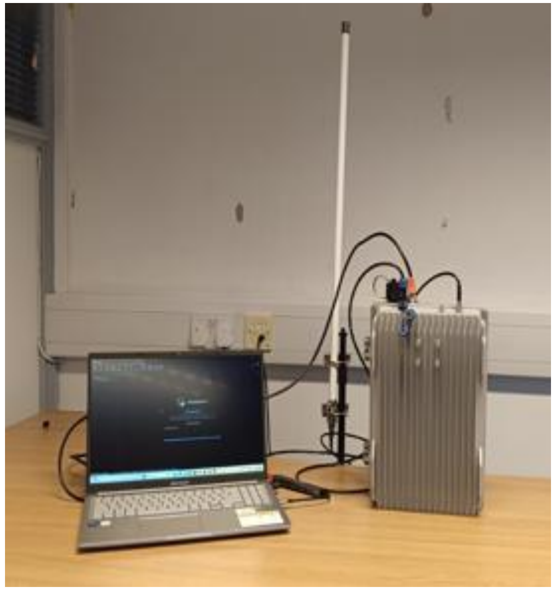
- DSA Client integration with DSA Server
- DSA Client integration with RAN
  - Band 3
  - Band n77
- Functions: Report RAN config information (MIB/SIB), control, RSRP measures, PLMN detection, Scanning,
- Ongoing DSA Client Integration with RANsemi PC802 radios



Planned Experiments / KPMs	Goal
RAN reports measurements to DSA Server and is granted operational parameters to transmit	< 1 minute
Time to evacuate RAN to protect new MNO spectrum usage	< 2 minute
MNO / PLMN detection sensitivity	-113 dBm
External TDD Alignment across RANs	Validation

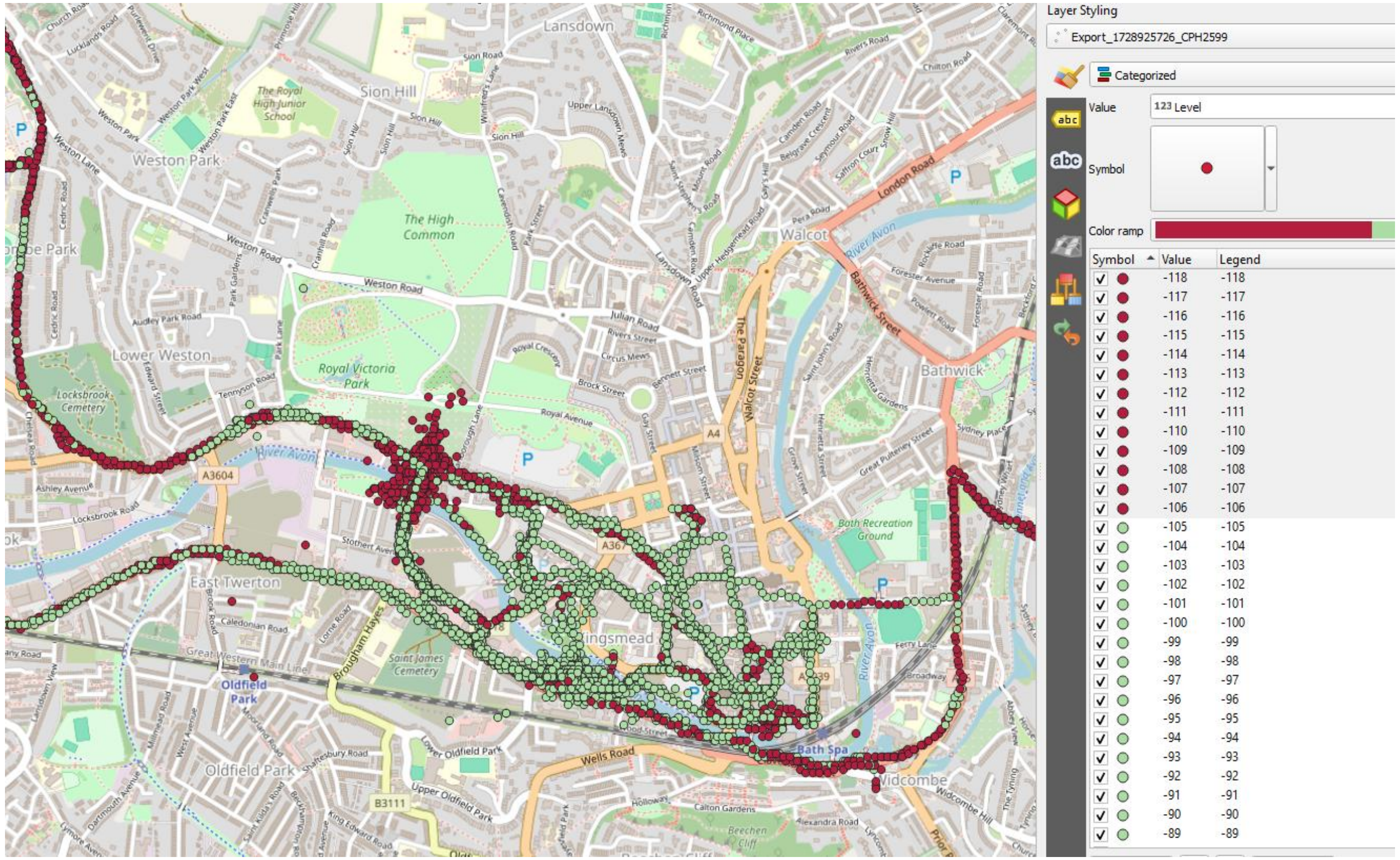
WP1: Prototype DSA system

- Demonstration systems using commercially available hardware operating in B3 (1800MHz) and n77 (4 GHz)
- Two different architectures:
  - Picocom/RANsemi PC802 chipset – both Band 3 (FDD) and Band n77 (TDD)
  - CellXica M3Q SDR – Band 3 only



WP1: Measurements (Bands 3 and n77)

- RSRP measurements around Bath
- Planned measurements in Liverpool, Worcs, and Central London
- Analysis of MIB/SIB capture to model spectrum use
- 'Look Through' to identify co-channel transmissions
- Cell data from fixed base station
- Describes current spectrum use at cell site
- Passed to DSA Server with request for spectrum lease
- Data used with data held at DSA Server to calculate interference profiles



Early results indicate significant under-utilised spectrum

WP1: DSA Server-Client Protocol Summary

- Machine-to-machine protocol with which the DSA Server and DSA Client exchange messages; documentation is a project deliverable, currently at v1.3
- REST (JSON over HTTPS), Client sends request to Server, Server responds to Client.
- Spectrum Access mechanism borrows from CBRS, AFC, and 5GNT
- Coexistence/reporting mechanism (TDD alignment) borrows from OnGo Coexistence protocol (CBRS extension)
- Basic mechanism derives from from OnGo Coexistence protocol (CBRS extension).
- **Extensions** to support the assumed DLAL/DSAL licensing:
  - “Dialects” for band- and jurisdiction-specific extensions
  - Measurements and Coexistence Messages can extend / accompany any Protocol message
  - Allows gNB to report measurements before requesting to transmit
  - (also supports non-gNB sensors)
  - Measurement reporting / instruction of PLMN
  - TDD alignment & time sources by group and to incumbent parameters
  - Mandated support for U/D split of 2/1

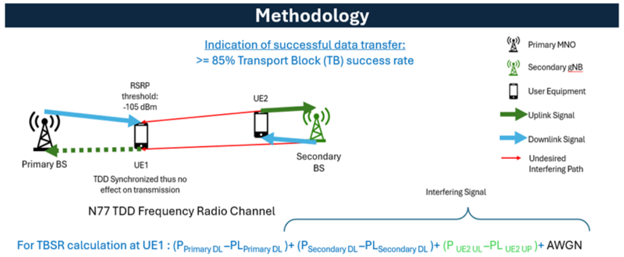
WP2: Simulation & Modelling

Protection Parameters

Issue: Practical interference protection threshold needs to be defined

Approach: Set threshold to TS 138.521-4 performance conformance test for sustained downlink (85% transport block delivery) at Ofcom coverage threshold (-105 dBm)

Threshold of **-105 dBm** for low AMC mode (QPSK) for TDD aligned sharing / FDD. Confirmed QPSK mode use from WP1 field measurements



Pathloss model

Rural Macro Cell

RMa	LOS	$PL_{RMa-LOS} = \begin{cases} PL_1 & 10m \le d_{2D} \le d_{BP} \\ PL_2 & d_{BP} \le d_{2D} \le 10km \end{cases}$, see note 5		$h_{BS} = 35m$
		$PL_1 = 20\log_{10}(40\pi d_{3D} f_c/3) + \min(0.03h^{1.72},10)\log_{10}(d_{3D}) - \min(0.044h^{1.72},14.77) + 0.002\log_{10}(h)d_{3D}$	$\sigma_{SF} = 4$	$h_{UT} = 1.5m$
		$PL_2 = PL_1(d_{BP}) + 40\log_{10}(d_{3D}/d_{BP})$	$\sigma_{SF} = 6$	$W = 20m$ $h = 5m$ h = avg. building height W = avg. street width The applicability ranges
	NLOS	$PL_{RMa-NLOS} = \max(PL_{RMa-LOS}, PL'_{RMa-NLOS})$ for $10m \le d_{2D} \le 5km$	$\sigma_{SF} = 8$	$5m \le h \le 50m$ $5m \le W \le 50m$
		$PL'_{RMa-NLOS} = 161.04 - 7.1\log_{10}(W) + 7.5\log_{10}(h) - (24.37 - 3.7(h/h_{BS})^2)\log_{10}(h_{BS}) + (43.42 - 3.1\log_{10}(h_{BS}))(\log_{10}(d_{3D}) - 3) + 20\log_{10}(f_c) - (3.2(\log_{10}(11.75h_{UT}))^2 - 4.97)$		$10m \le h_{BS} \le 150m$ $1m \le h_{UT} \le 10m$

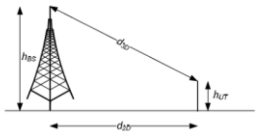
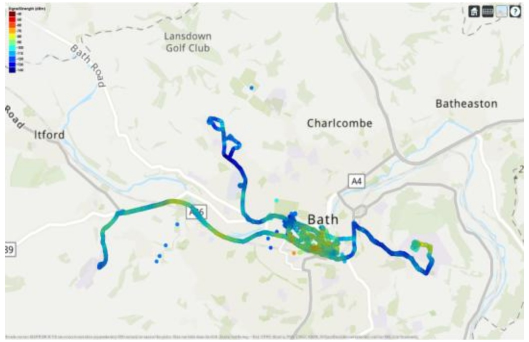


Figure7.4.1-1: Definition of d_{2D} and d_{3D} for outdoor UTs

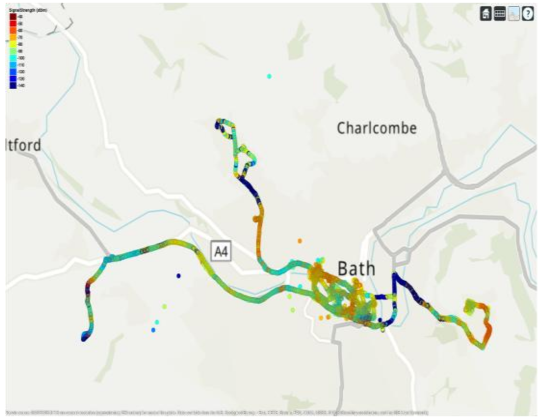
To follow: Band n77 when WP1 measurements are ready

Other Studies: Impact of TDD alignment, reduction in prediction margin of error from ray tracing (validated with WP1 field measurements)



WP1: Field measurements (Band 3)

Key Parameters	Values
Base station Transmission Power	37dBm
UE Transmission Power	23dBm
Carrier frequency	4079MHz
Carrier bandwidth	5MHz
Subcarrier spacing	15KHz
Resource block	25
Reference signal configuration	DM-RS& PT-RS
Channel model	Tapped delay line (TDL) MIMO link-level fading channel.
Noise power	-107dbm
Delay Profile:	TDL-C'
Delay Spread:	0.00000003
Maximum Doppler Shift:	5
Sample Rate:	7.68MHz
MIMO Correlation:	'Low'
Polarization:	Co-Polar'
Transmission Direction:	'Downlink'
NumTransmitAntennas:	4
NumReceiveAntennas:	4
Initial Time:	0
Num Sinusoids:	48
Random Stream:	'mt19937ar with seed'
Seed:	73
ChannelResponseOutput:	ofdm-response'



WP2: Ray Tracing analysis

- The graph illustrates the transport block success rate versus gNB power levels, confirming the -105 dBm threshold for QPSK mode. This ensures a practical and reliable interference threshold for deployment scenarios.
- Additional studies examine the impact of TDD alignment and reduction in prediction margins of error, validated by WP1 field data and WP2 ray tracing.

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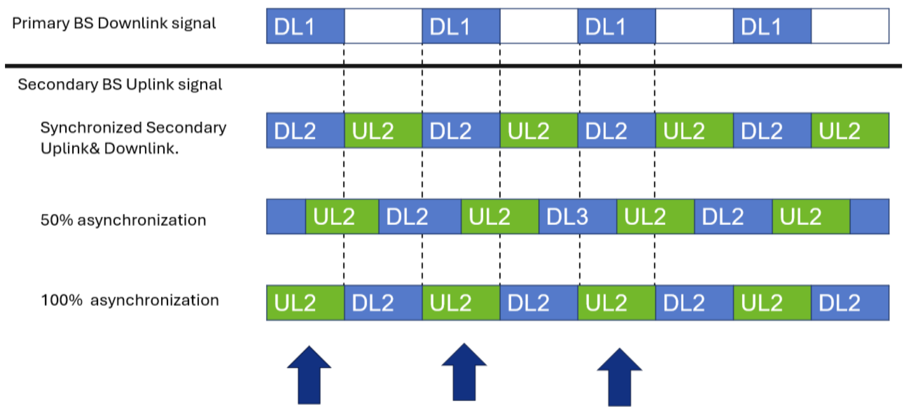
WP2: Simulation & Modelling – N77

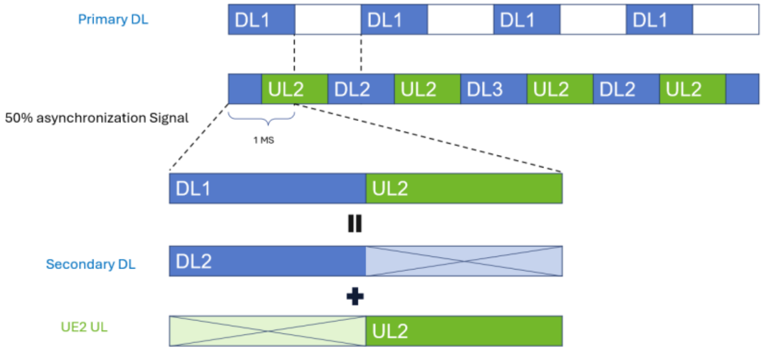
Protection Parameters

Synchronised Scenario: Uplink (UL) downlink (DL) signals from primary and secondary base stations are aligned.

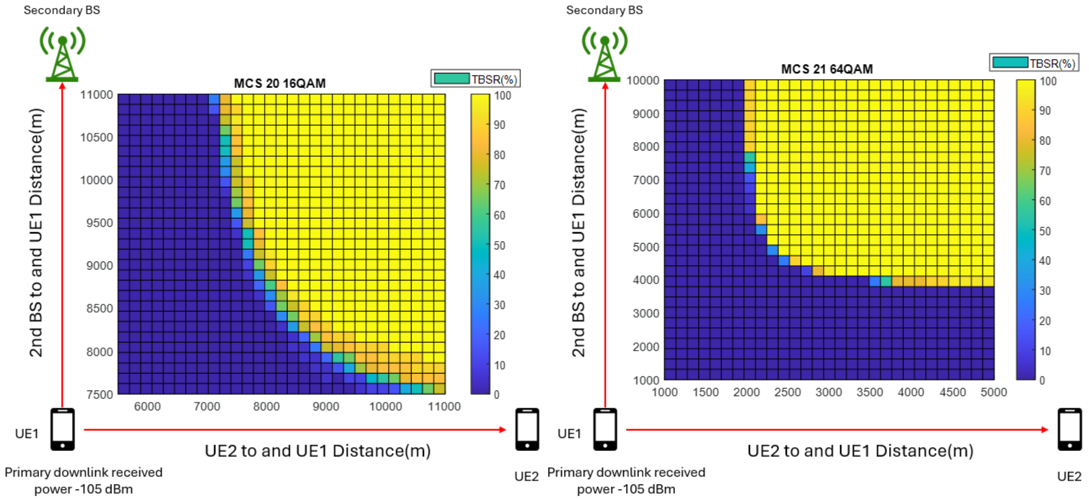
Asynchronised Scenarios: Two cases are shown:

- 50% Asynchronization: Partial misalignment between UL and DL signals.
- 100% Asynchronization: Complete misalignment between the two base stations' TDD cycles.





TDD asynchronization TBSR



Key Takeaways:

1. Asynchronisation between TDD cycles introduces significant interference that affects the reliability of transport block success rates, particularly in dense deployments.
2. Higher modulation schemes (64QAM) are more sensitive to interference, requiring stricter synchronization and power management.
3. These results will guide the development of protection parameters and interference management strategies for future N77 deployments.

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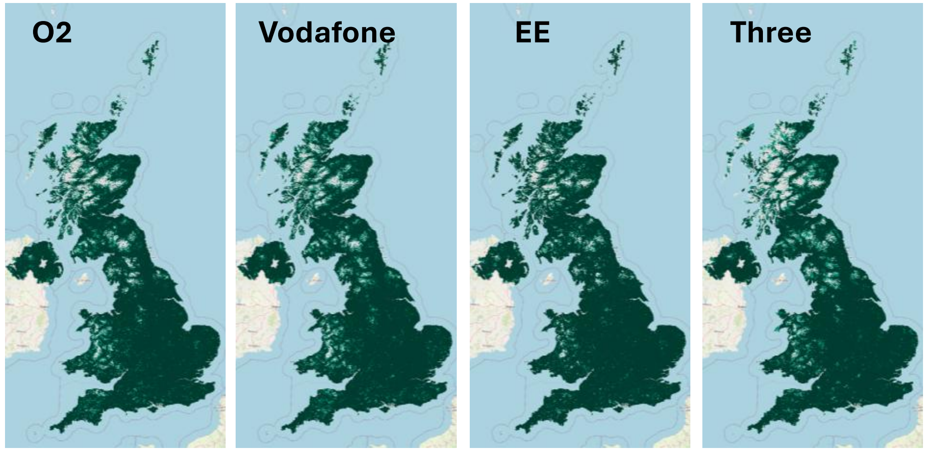
Output: See WP3 slide

WP2: Assessment of spectrum availability

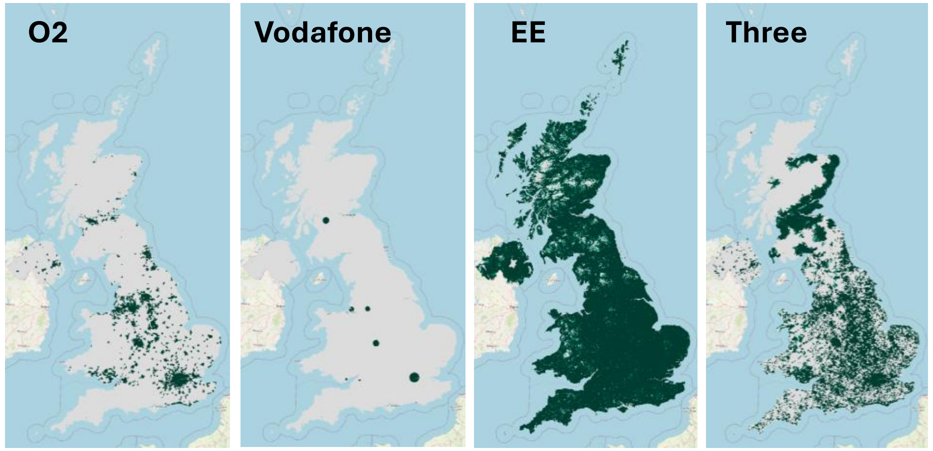
1 Raw input

Ofcom's public (consumer-grade) coverage data isn't per-band – it doesn't show where Band 3 is under-utilised:



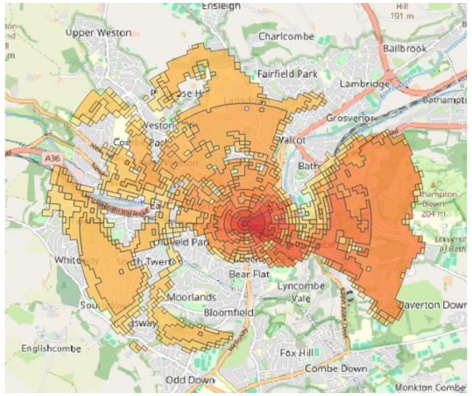
2 Modelled input

Filtered by census area ‘ruralness’, to give a more realistic picture – broadly matches crowd-sourced Band 3 coverage



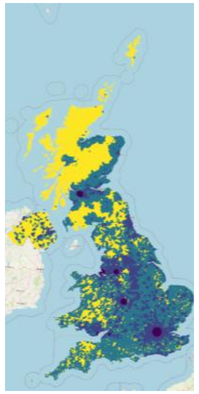
3 Simulation

Used DSA Server (WP1) to model areas in which Band 3 spectrum can be used by other users, factoring in protection parameters (WP2)



4 Output

Nationwide plots of spectrum availability, used as an input to economic and societal impact study for use cases of licences (WP3)



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This is not how a production DSA Server would model MNO coverage!

WP3: Overview of economic modelling

Methodology of cost-benefit analysis

1. Identify main use cases which would benefit from dynamic access to spectrum
2. Identify benefits associated with dynamic access
3. Assess the changes in demand compared to the counterfactual
4. Quantify the benefits associated with dynamic access
5. Quantify the additional costs associated with dynamic access
6. Combine benefits and costs from the different use cases
7. Assess other benefits and costs that are independent of the use case e.g. spectrum access database

Use cases

Local mobile providers (LALs)

- Public and private mobile networks deployed by local providers
  - for example, private networks covering holiday parks or campsites
  - providing coverage in 4G/5G not-spots and partial not-spots
  - localised areas notionally covered by mobile operators but where user experience is inadequate

Fixed Wireless Access (LALs)

- Additional source of 'low cost' spectrum for Fixed Wireless Access networks, leading to increased capacity and coverage of Fixed Wireless Access networks
- Increased availability of superfast broadband over FWA

Additional spectrum for national mobile operators (LALs)

- Use of spectrum by a different mobile operator in an area where the specific frequencies are not being used by the licensed mobile operator
  - Similar to the use of CBRS spectrum in the USA by the national mobile operators

Other local uses (SALs and LALs)

- Short-term capacity in a local area, e.g. for festivals, news broadcasts, sports events, other visitor attractions (SALs)
- Use of lower frequency ranges for deployments of private networks for use cases that require wide-area coverage, e.g. ports, universities (LALs)

WP3: Example of benefits calculation

For each use case, we calculate the size of the opportunity for incremental deployments due to DSA and quantify the associated net benefit per deployment (benefits less costs)

~**344 DL MHz×Mpop** is available for use in Band 3 (**7.7% increase** to existing MNO usage) – usable by local operators in mobile not-spots

We estimate addressable market for local mobile providers (population living in not-spots that could be economically covered) and consider the expected benefits and costs for each deployment

Examples of sources of benefit from extending mobile connectivity

General economic impact

Improved connectivity boosts the local economy by enabling flexible working and enhancing overall productivity

Wellbeing impact

Access to connectivity reduces the digital divide, enhances quality of life, and generates consumer savings

Construction and maintenance impact

The construction and maintenance of telecoms infrastructure drive local job creation and contribute to the British economy

WP2: Available Spectrum in Band 3 / MHz × **Population in Total Not-spots**

Summary of project outputs

We have developed a sandbox demonstrating the technical feasibility of dynamic assignment spectrum usage within DLAL and DSAL licences

WP1	WP2	WP3

• End-to-end prototype DSA system developed:
  • DSA Server assigns spectrum to avoid harmful interference
  • Middleware interface between DSA server and radios
• Prototype scanning commercial radios built
	• High-fidelity link simulation
	• Nationwide simulation performed with WP1 DSA Server
		• Economic assessment approach developed (Q1)
		• Economic benefits assessment to be completed (Q4)
		• Regulatory implementation requirements to be completed (Q4)

Key findings

- More Band 3 spectrum is available for shared use than expected
- Practical problems of LALs can be solved with DLALs
- Scope for greater sharing of Band n77
- Results detailed in a paper submitted to IEEE DySPAN 2025

Next steps (for remainder of project)

WP1

Aim: Provide practical measurements for WP2 & WP3

- DSA proof of concept prototype experiments:
  - Radio using spectrum assigned by DSA Server
  - Radio switching off in event of interference detection
- Collate additional Band 3 and Band n77 usage data across more urban areas

WP2

Aim: Run detailed simulations to understand applicability

- Enhance ray-tracing model into the existing simulations
- Improve simulation of urban areas (multi-path effects)
- Complete investigation of different TDD synchronisation schemes
- Update maps of spectrum availability (Band 3, n77)

WP3

Aim: Economic and social impact study of use cases

- Economic assessment:
  - Complete assessment of costs and benefits for each use case
  - Assess overall costs and benefits of introducing DSA
- Understand regulatory changes required to implement DSA solution and develop roadmap

Further steps (post project completion)

Research question	What we have / will have accomplished	Future steps (outside scope of this project)
How well does the proposed spectrum sharing mechanism work?	We have demonstrated that the spectrum sharing mechanism operates through a TRL level 6 proof of concept	Extend the TRL 6 POC to TRL 8 with a larger number of cells operating in a real-world environment
Can the current generation of commercial small cells be adapted to integrate with DSA server and obtain spectrum leases in real time?	We have worked with Ransemi, and CellXica to extend the functionality of current generation small cells to include: - spectrum scanning and sensing, and - integrated them with the DSA server	Build on existing work to develop production-ready small cells that offer spectrum sensing and DSA server integration
Can a centralised dynamic spectrum sharing mechanism be built that clearly demonstrates that additional spectrum is available?	We have built a DSA server prototype that demonstrates real-world efficacy real-world time in a real-world environment	Work with Ofcom to extend/define coexistence algorithms and data provision suitable for a fully commercial and regulatory environment
What is a realistic interference coexistence arrangement?	We have simulated interference in both FDD and TDD domain using real-world signal data to validate the model	Extend the current models and simulation to make better use of collected data along with AI and improved environment data

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