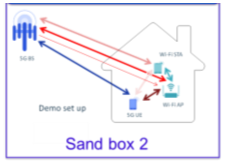
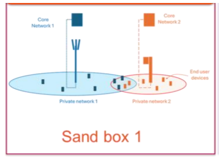
Real Wireless led Spectrum Sandbox project

UK SPF Cluster 3 event

14 January 2025



Sandbox 1

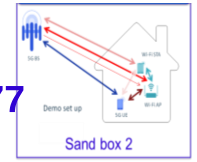


Sandbox 2

Agenda

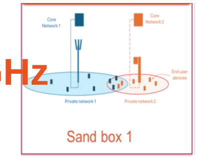
1. **Introduction** to Real Wireless led spectrum sandboxes

WP1-N77



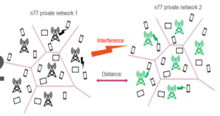
2. **Sand box 1:** Private networks operating in the n77 band
   a) Interference prediction for SAL assessment
   b) Interference tolerance measurements and licensing process improvement

WP1-U6GHz



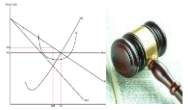
3. **Sand box 2:** Wi-Fi and mobile in the upper 6 GHz band

WP2



4. **WP2:** Assessment of scalability and impact through simulation and modelling
   a) Cross technology signaling performance assessment for Mobile and W--Fi sharing

WP3



5. **WP3:** Economic assessment and regulatory consideration
6. Summary and Q&A

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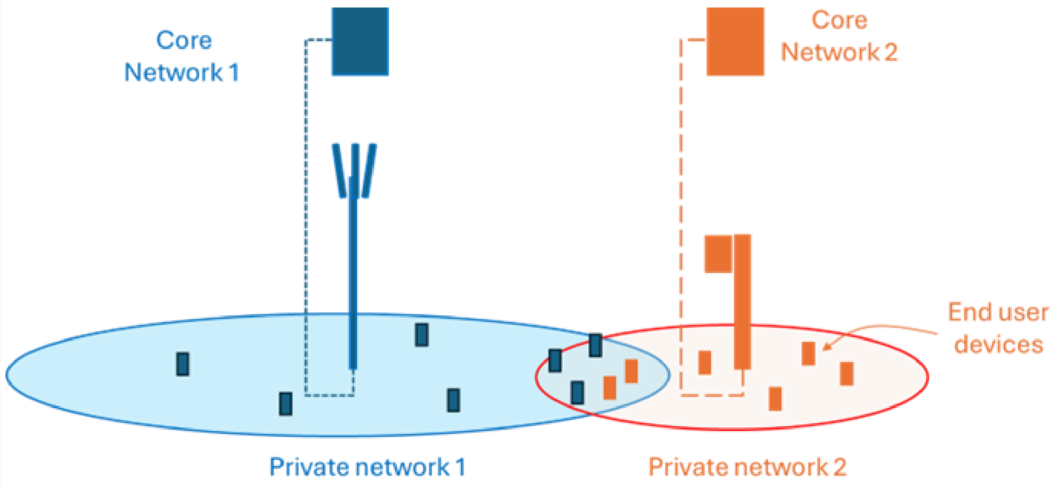
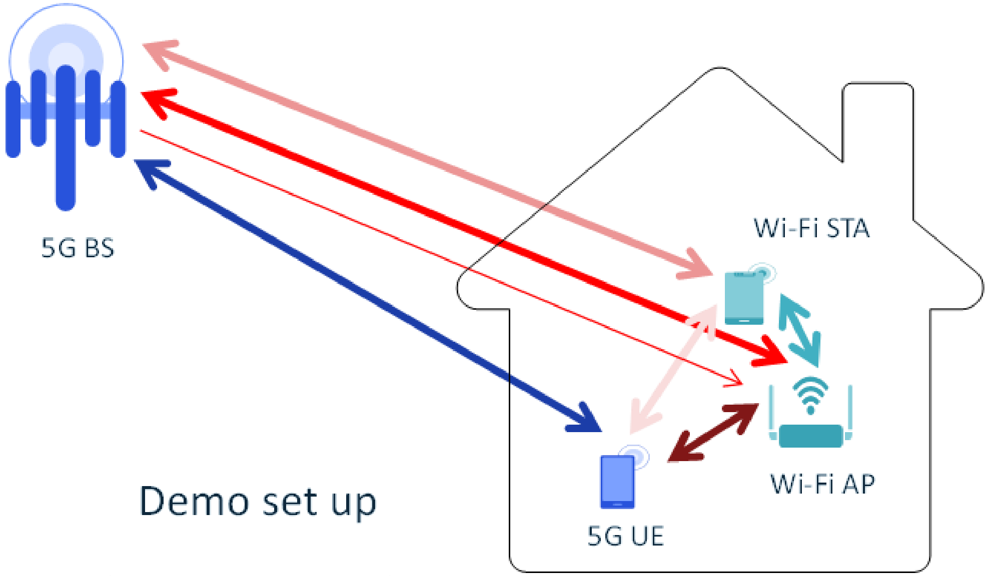
Real Wireless led spectrum sandbox project –
We implement 2 Sandboxes to conduct field trials

Independently operated private networks in upper n77



Sand box 1

Wi-Fi and mobile in the upper 6 GHz



Sand box 2

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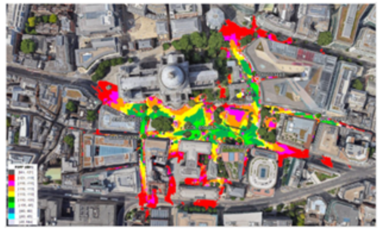
Our roadmap of solution development for private networks includes two steps

Today's SAL licensing process

User applies for band, location, bandwidth, and power required → Ofcom assesses interference to/from other users → User pays licence fee (per channel and per area/base station). → Ofcom grants per area/per base station licence

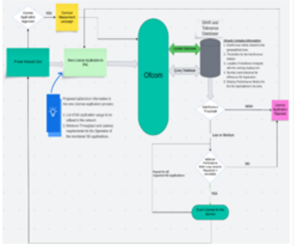
Step 1: Improve prediction

- Improved interference prediction model for SAL assessment



Step 2: Intelligent service-aware licensing

- Make use of interference tolerance ability to intensively share spectrum by different services and deployments



More intensive spectrum sharing, by:

1. reducing the sterilization zones
2. Utilising interference tolerance ability

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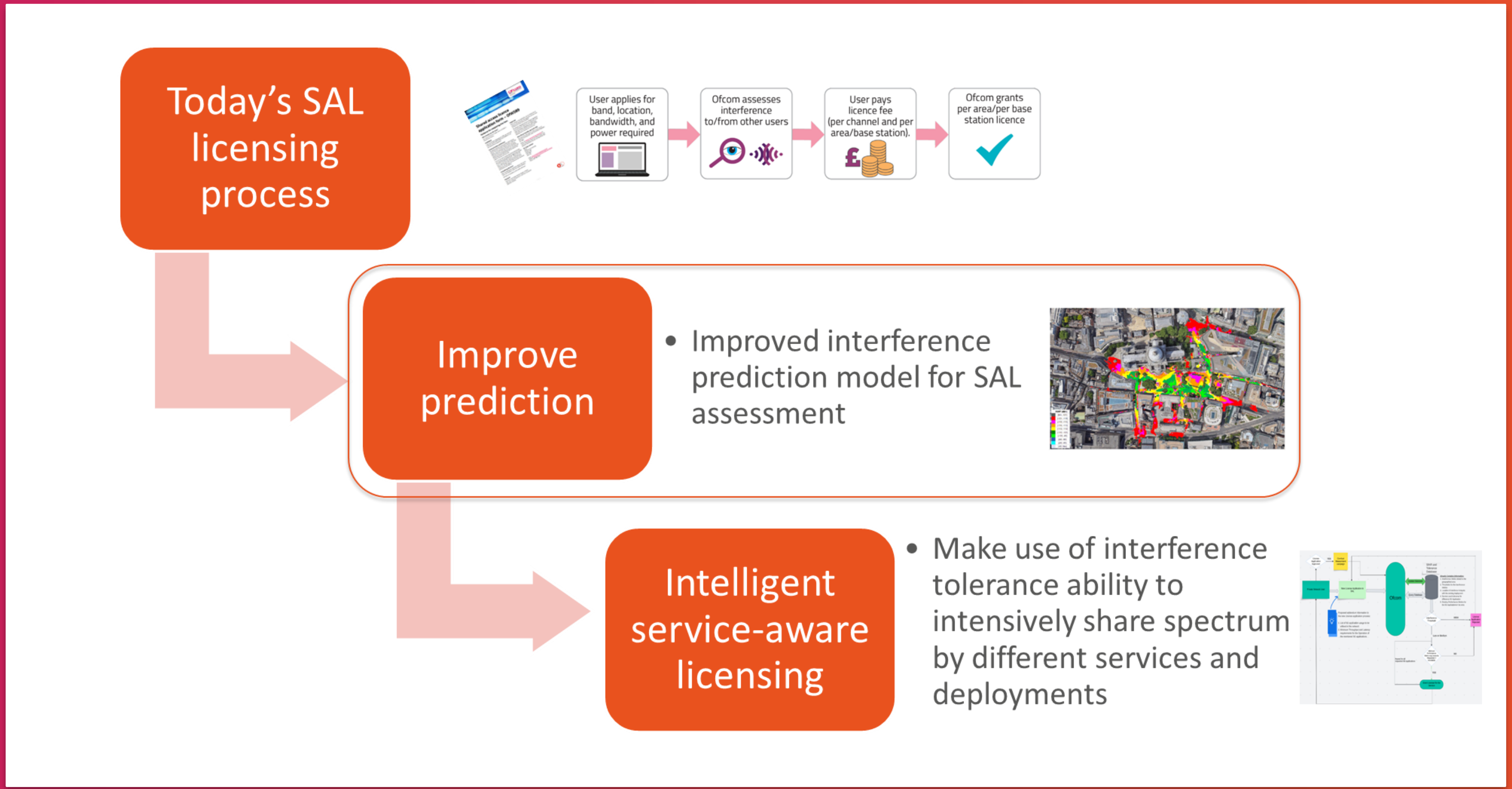
2. Spectrum sandbox 1: Private networks operating in the n77 band

2(a) Interference prediction for SAL assessment



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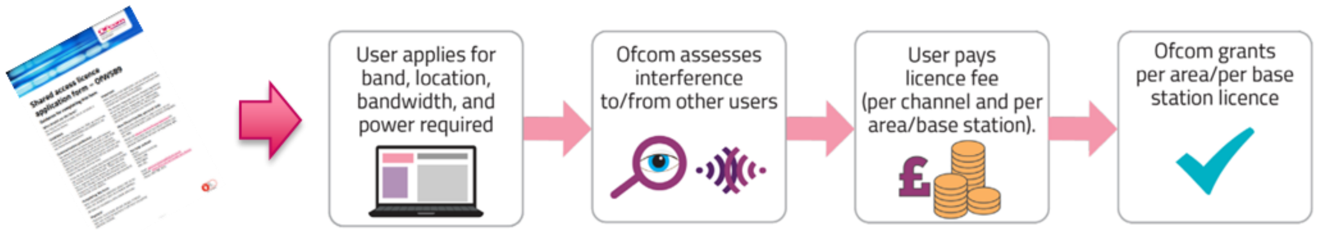
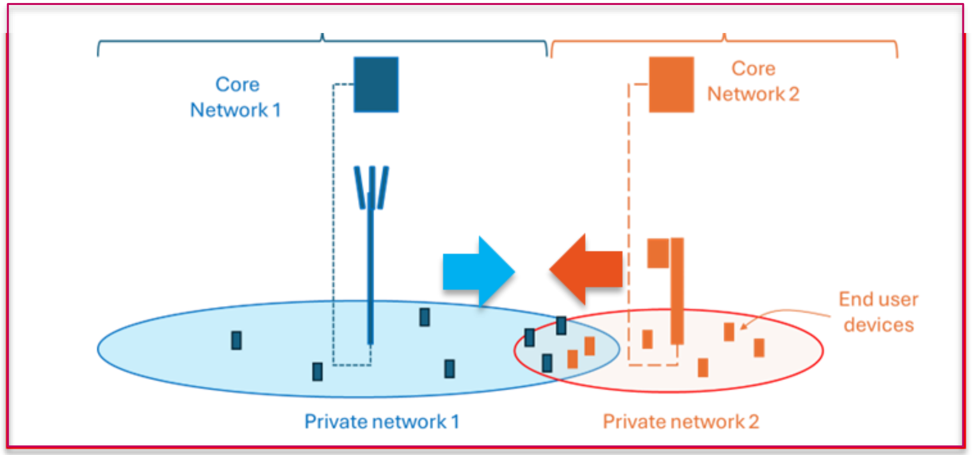
We aim to improve the current process by utilising more accurate propagation models

- Study questions we address: ***“Better Data:*** *The extent to which* ***deployed network equipment*** *and* ***user devices*** *can make* ***measurements*** *of the radio environment that can* ***inform regulatory operational*** *and* ***policy activities*** *and form the basis of more adaptive and dynamic spectrum authorisations in the future.“*
- The current process heavily relies on propagation model prediction





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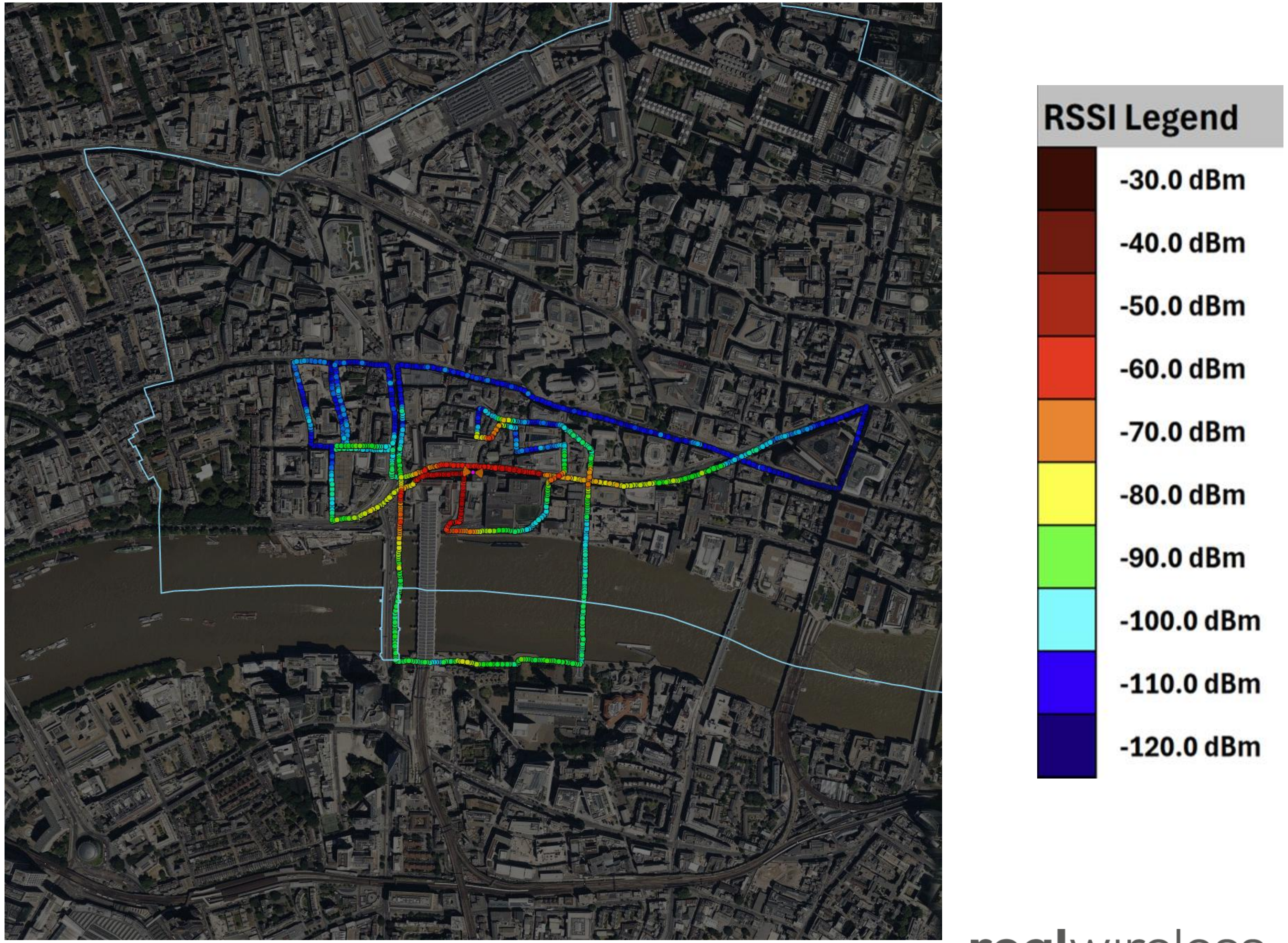
Interference prediction - surveys

Median surveyed RSSI levels for Loc10A5, 2 x 2 km” with “Measured RSSI levels for one of the surveys at site Loc10 in the City of London, 2 x 2 km



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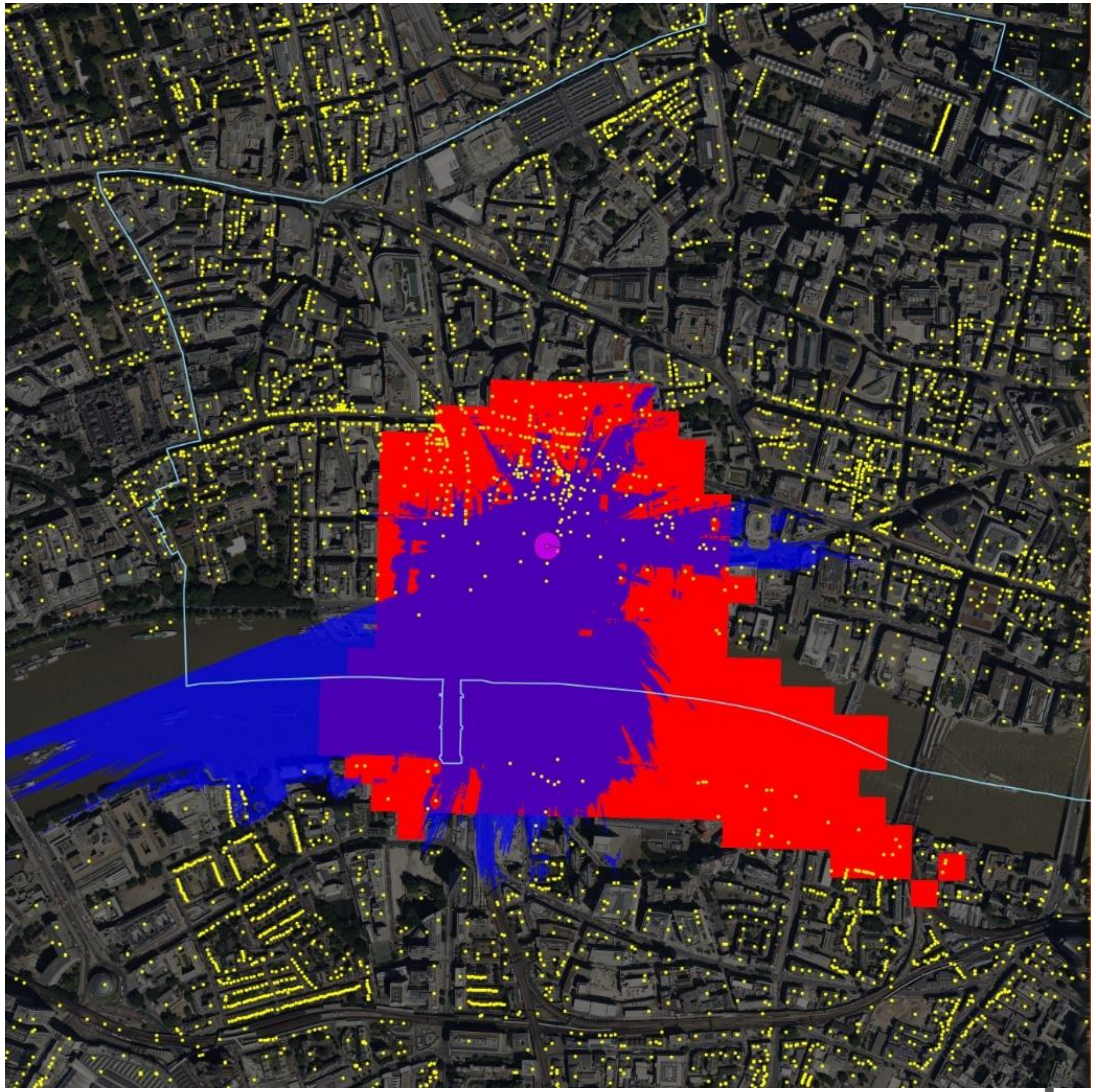
Interference prediction - results

Comparison of sterilised area predicted by Ofcom (red) and the calibrated project model (blue) for site Loc10; the project premises database is shown by the yellow dots



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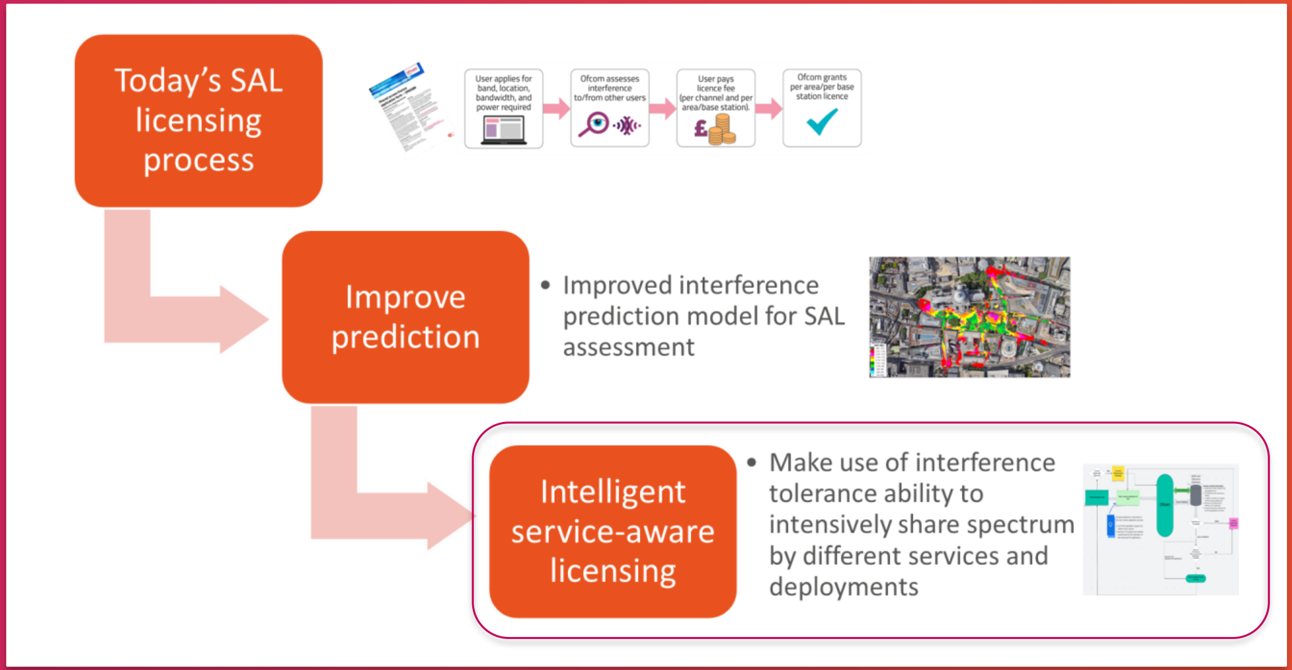
2. Spectrum sandbox 1: Private networks operating in the n77 band

2(b) Interference tolerance measurements and licensing process improvement



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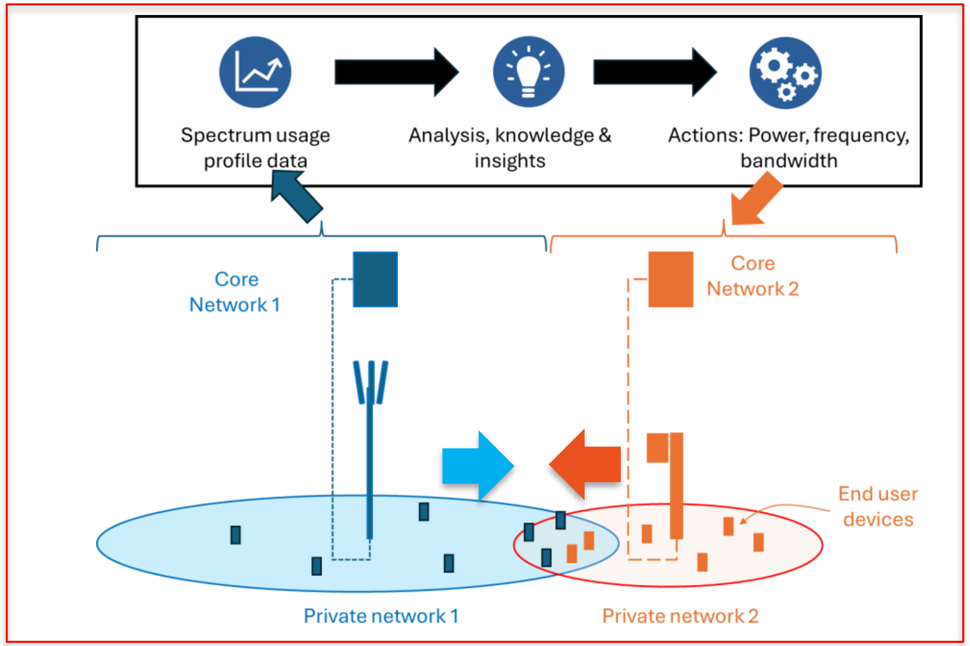
Exploring the interference tolerance ability of different services in private networks

- Study questions we address **to share spectrum intensively**:
  1. *“**Better Data:** The extent to which deployed network equipment and user devices can make measurements of the radio environment that can inform regulatory operational and policy activities and form the basis of more adaptive and dynamic spectrum authorisations in the future.“*
  2. *“**Interference tolerance**: How much **more intensively can different services** and deployments share spectrum **without causing harmful interference** to each other?”*



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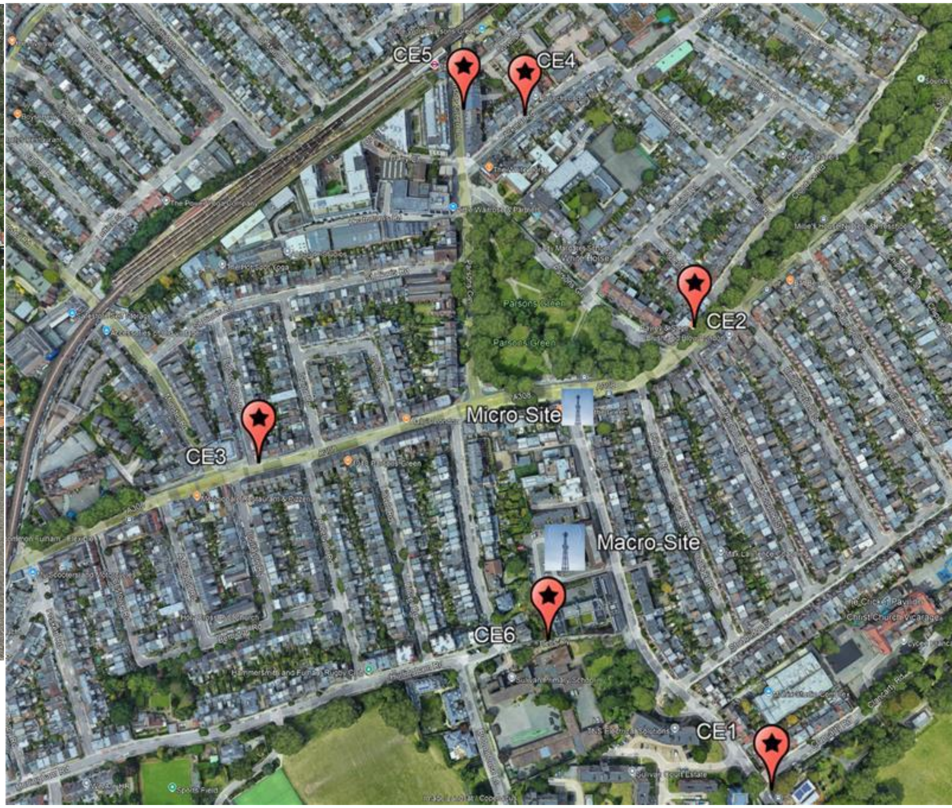
Measurement Campaigns from the Sandbox



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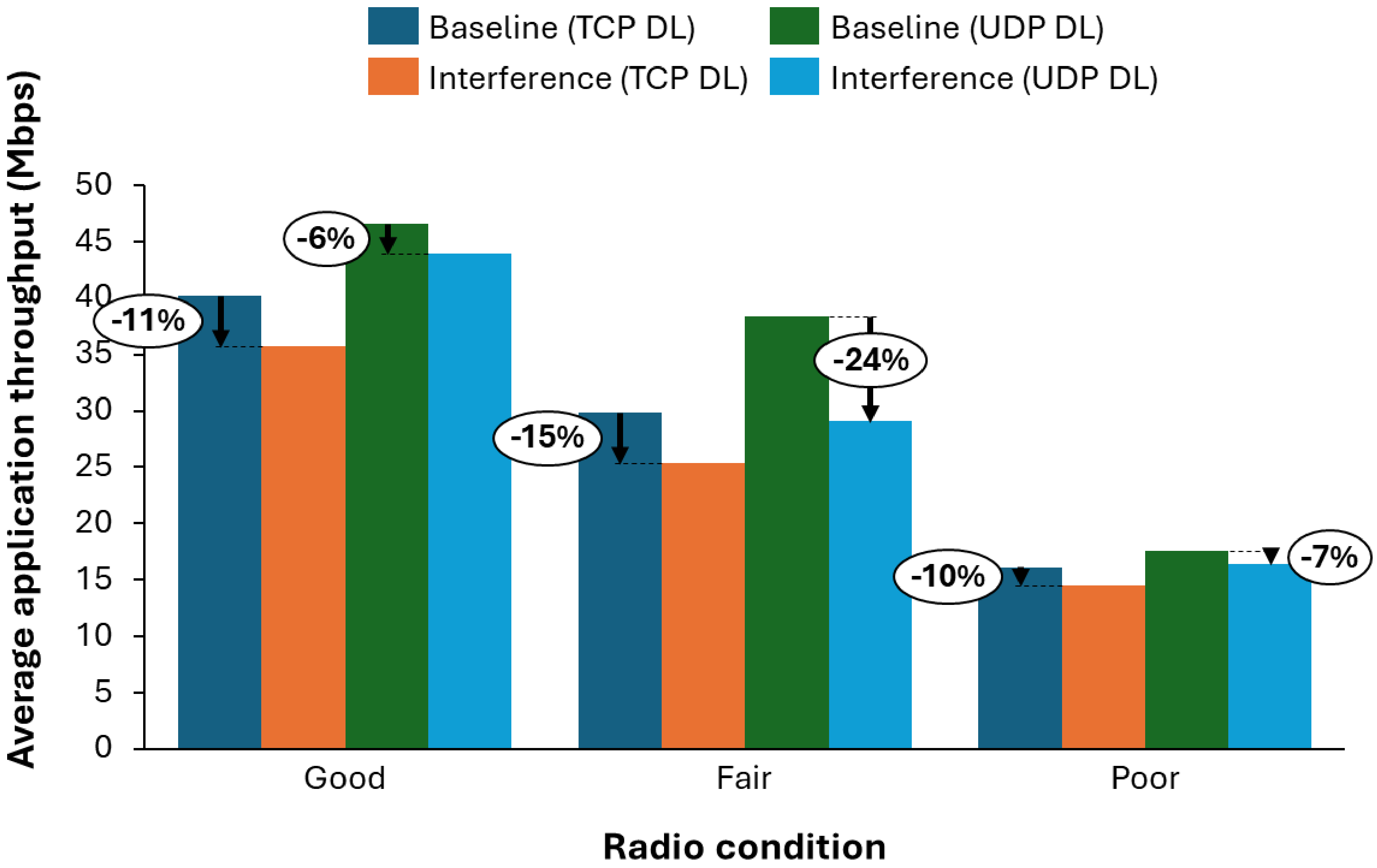
Assessing the performance of the systems in the test environment



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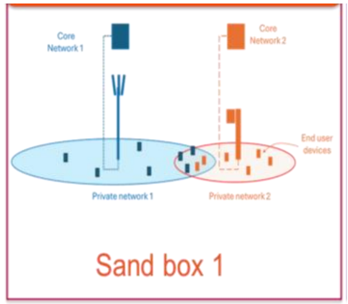

WP1-U6GHz

3. Spectrum sandbox 2: Wi-Fi and mobile in the upper 6 GHz band

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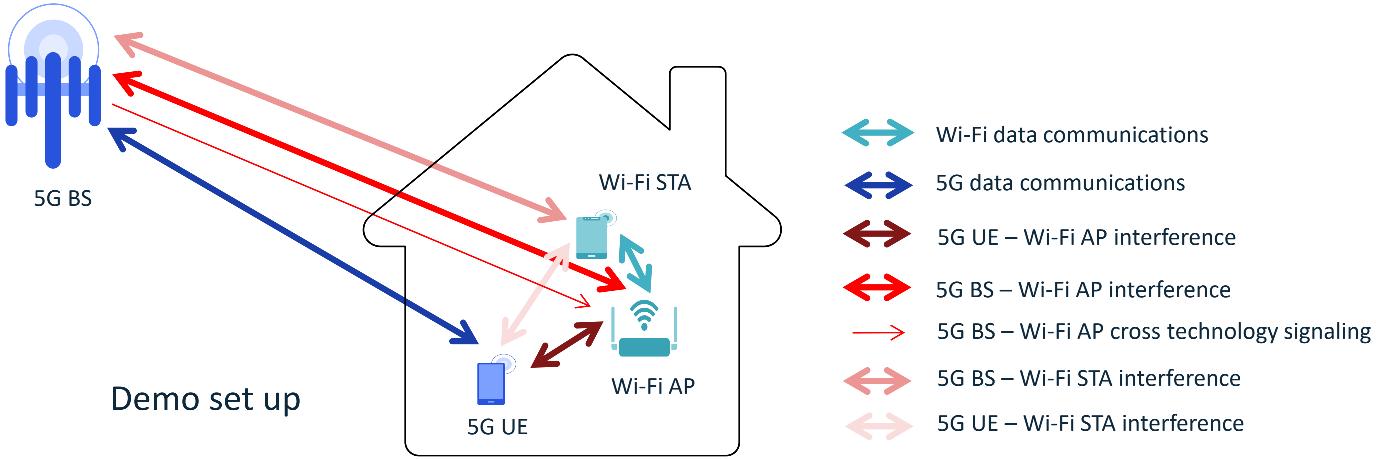
Introduction to our sandbox test bed activities

- The objective of the test plan is to **evaluate potential for shared use of spectrum** between **Mobile and Wi-Fi** deployments in an **overlapping geographical** area.
- Compare KPIs of both technologies for insolated deployments and "**collocated**" scenario where **Wi-Fi is deployed indoor** and **Mobile base station outdoor** .



- If Wi-Fi is deployed in an area with good mobile coverage, interference from the BS is expected to degrade the Wi-Fi service. When the mobile UE is in the vicinity of a Wi-Fi deployment, UE and Wi-Fi performance is expected to be degraded. The mobile service BS's receiver performance may also be impacted, particularly when there are many simultaneously active Wi-Fi devices within the base station coverage area.
- The goal of the sandbox is to study whether **new technologies** and **methodologies** can **deliver net benefits** in terms of more **efficient use of spectrum** and flexibility in the cost and performance of wireless systems.
  - The extent to which deployed network equipment and user devices can make measurements of the radio environment that can inform regulatory operational and policy activities and form the basis of more adaptive and dynamic spectrum authorisations in the future.

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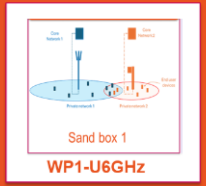
Innovation: Study new technology and methodologies



- Use of **cross-technology signalling (XTS)** was proposed as a tool to identify scenarios where service degradation occurs due to interference coming from different co-channel operations.
  - Only one technology can use the resources where conflict occurs, and the service of the other technology need to be temporarily reduced.
  - If there is no conflict it may be possible to increase utility of spectrum by allowing access to booth services.
- The study will evaluate multiple practical scenarios of interest accounting for potential of occurrence and impact hidden node interference to Mobile service base station and devices
- Broadcast Wi-Fi waveform solution demonstrated in the sandbox may utilize IEEE 802.11bc Uplink frame with Higher Layer Payload (HLP) simplifying future standardization
- From MFCN perspective, it is also important that the functionality is properly standardised, harmonised and compliance tested as a pre-condition for deployment

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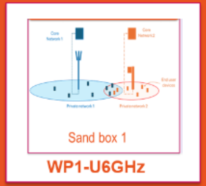
Innovation: Influencing CEPT PT 1 activities



- The work on sharing between outdoor Mobile and Fixed Cellular Network (MFCN) and indoor Wi-Fi deployments is ongoing in CEPT PT 1. PT 1 is working on the technical report (TR) to document various proposed solutions, with expected completion in 2025.
- The requirements for mobile and Wi-Fi in the upper 6 GHz are conflicting. Indoor Wi-Fi deployments would benefit from the reduced EIRP limits imposed on mobile service base stations. However, any value lower than the standard EIRP limit (~83 dBm/100 MHz) for macro deployments could significantly reduce MFCN coverage area, particularly indoors.
- Cross-technology signalling was proposed as a tool to prevent service degradation when concurrent use of resources is not practical. Many cross-technology signalling solutions are proposed that can be classified as Mobile service (MFCN) waveform based, and Wi-Fi waveform based. In spectrum sharing sandbox 2 we evaluate Wi-Fi waveform-based broadcast solution.
- Motivations for selecting Wi-Fi waveform-based broadcast solution for spectrum sharing sandbox demo:
  - More economical than Mobile service waveform-based since associated cost can be more easily absorb by Mobile service base station than including Mobile service receiver in Wi-Fi APs
  - Broadcast Wi-Fi waveform allows practical implementation by Mobile service base stations. It is impractical for Mobile service base station to send signals in unicast manner to all Wi-Fi APs in its coverage area.

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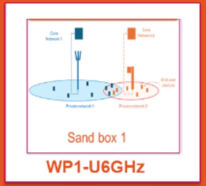
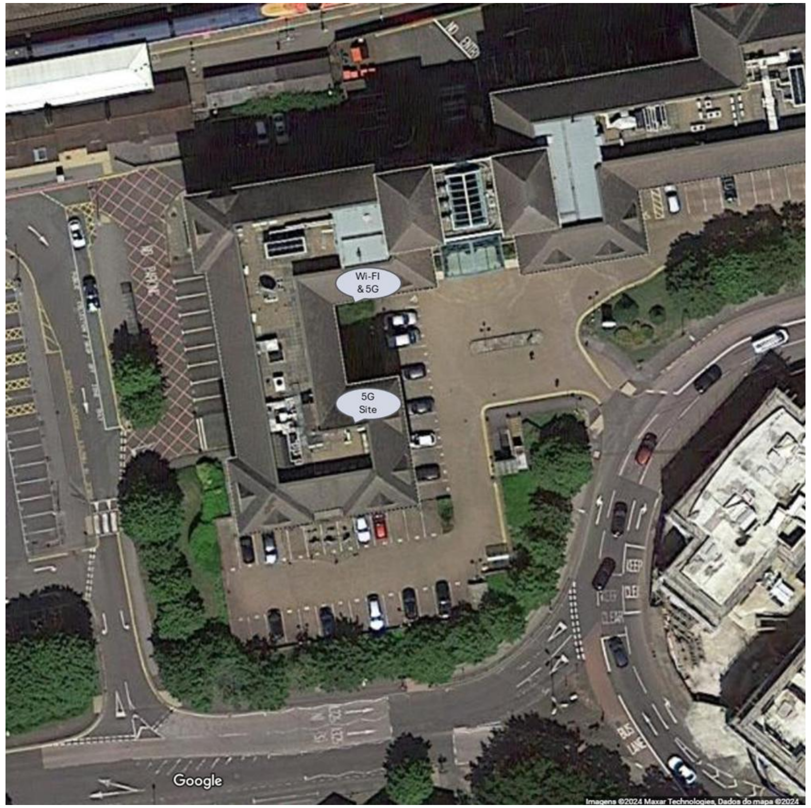
Sandbox setup

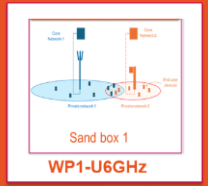


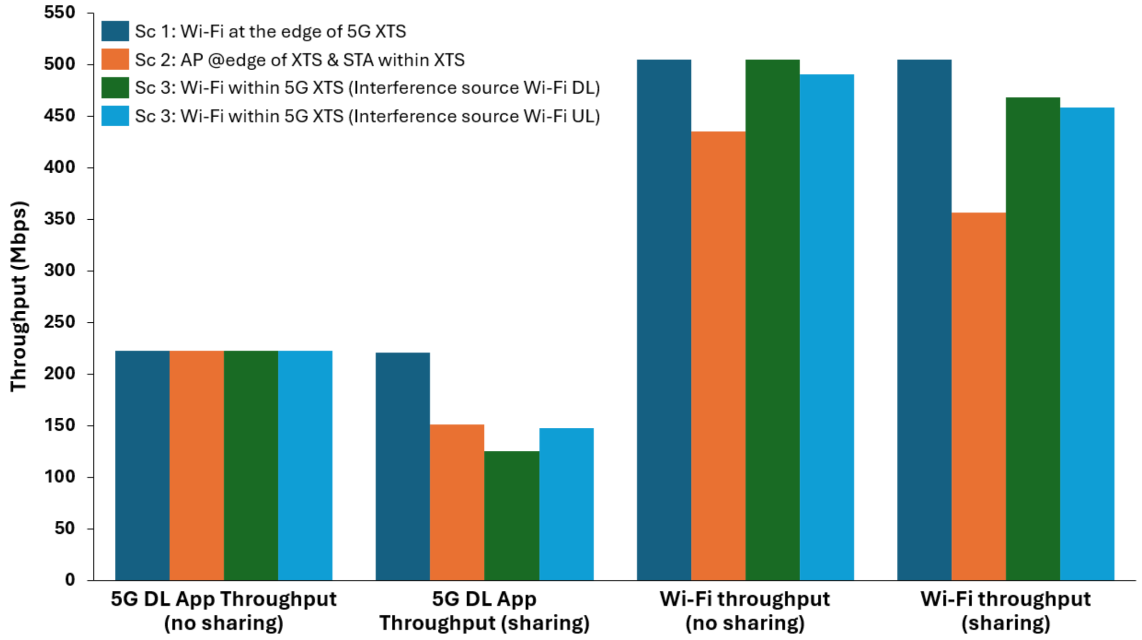
Test equipment set up for demonstrating the impact of intense use of spectrum on 5G and Wi-Fi.



5G site, 5G device and reference Wi-Fi system location

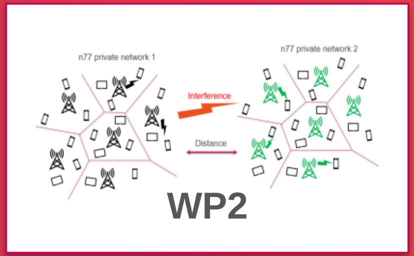
Initial example results and findings from the sandbox





- Marginal impact on 5G performance if Wi-Fi deployment is outside the range of cross-technology signaling
- 5G system design is optimised for exclusively licensed deployments and bursty, intermittent interference from Wi-Fi can negatively impacts 5G performance

Scenario	Interference source	5G BS to Wi-Fi AP XTS signal strengh (dBm)	5G BS to Wi-Fi STA XTS signal strength (dBm)	5G UE to Wi-Fi AP XTS signal strength (dBm)	5G UE to Wi-Fi STA XTS signal strength (dBm)	5G throughput loss [%]	5G average DL MCS (sharing)	5G SS RSRP (dBm)	Wi-Fi STA RSSI (dBm)
Sc 1: **Wi-Fi** system deployed at the **edge of 5G XTS** coverage transmitted by 5G BS and UE.	DL/UL Wi-Fi	-81	-81	-81	-81	<1%	22	-83	-43
Sc. 2: **Wi-Fi AP** deployed at the **edge of 5G XTS** coverage, while **Wi-Fi STA** is located **within the XTS** coverage.	DL Wi-Fi	-81	-71	-81	-70	32%	14	-83	-50
Sc. 3: **Wi-Fi** system is deployed **within 5G XTS** coverage.	**DL** Wi-Fi	-71	-71	-70	-70	44%	12	-83	-43
Sc. 3: **Wi-Fi** system is deployed **within 5G XTS** coverage.	**UL** Wi-Fi	-71	-71	-70	-70	34%	14	-83	-43



4. WP2: Assessment of scalability and impact through simulation and modelling

4 (a) Cross technology signaling performance assessment for Mobile and Wi-Fi sharing

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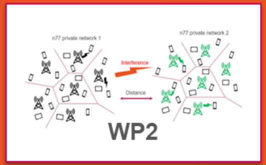
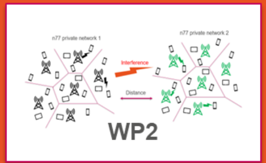
IMT Base Station cross technology signalling antenna beam choice

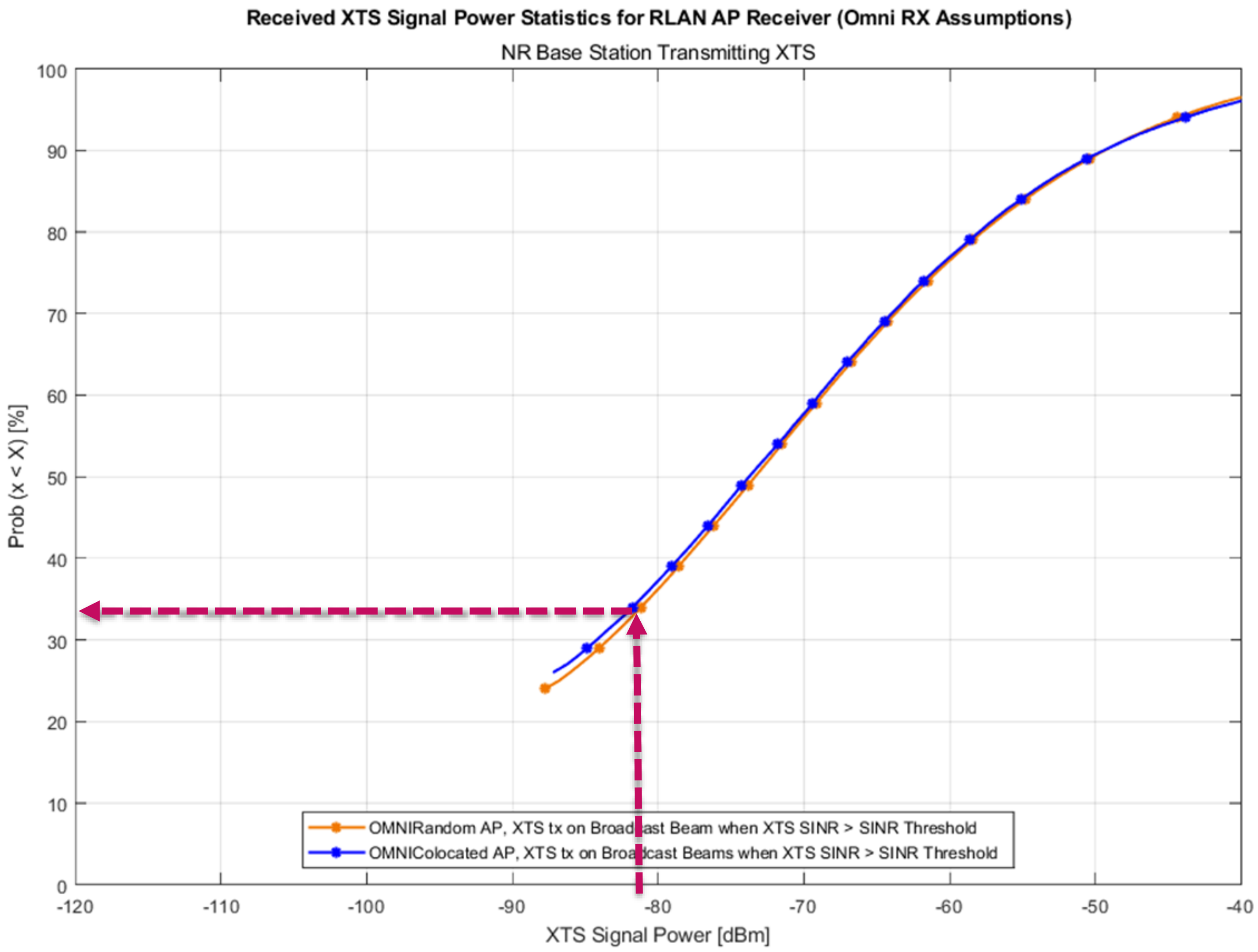


- There are two options for transmission of Cross Technology Signalling (XTS) when the simulation is based on transmission from the IMT Base Station:
  - Using beamforming associated to data transmission (data beams)
  - Using beamforming associated to broadcast transmission (broadcast beams)
- The use of data beams allows for a more directional transmission and higher spatial selectivity while, due to the broadcast nature of the XTS transmission, it is possible that broadcast beams (e.g. SSB beams) might be more suited. The beam choice also has an impact on the design of the XTS scheduling, WLAN detection periodicity requirements, and time before accessing the channel.
- A sensitivity analysis of the sharing technique comparing different beam choices is included in the results below.
- For the beamforming choice of broadcast transmission, the design is based on a number N=8 beams which are assumed to be equally distributed in the sector's azimuth domain (120 degrees). Further optimisation or differences cannot be excluded when evaluating more realistic implementations.



Performance analysis: IMT Base Station as Source for XTS

- The figure shows the statistics of the XTS received signal strength.
  - CDF of the received signal strength of the XTS transmission only if XTS SINR > SINR Threshold
  - For example, with the example parameters show in the results in this slide for a –82dBm/20MHz threshold, around 67% of Wi-Fi AP will vacate the channel.



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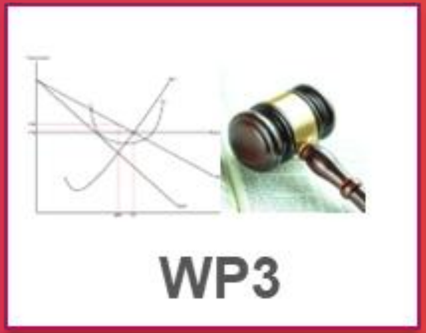
5. WP3: Net benefit assessment e.g. Mobile and Wi-Fi sharing



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Modelling approach for economic cost benefit assessment

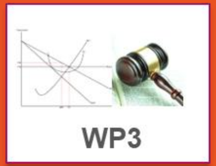
WP3

- **Technology Pair**
  Scenarios vs counterfactual
  - **WP1/2 KPI outputs:**
    E.g. Download speed
    Capacity
    Separation distances
  - **WP1/2 sharing solution info:**
    Incremental changes to network / equipment

Economic welfare

- **Better network performance for existing users**
  - Higher WTP: Increased consumer surplus
  - Higher WTP: Increased operator revenue/profit
  - Lower opportunity cost: Reduced need to expand capacity etc.
- **Additional users supported**
  - Consumers: Increased consumer surplus & operator profit
  - Vertical users: Additional value - cost savings, productivity, etc.
- **Incremental changes for sharing solution**
  - Directly attributable: Additional costs of sharing, e.g. upgrades
  - Capacity driven: Equipment costs to support extra capacity

Net benefit assessment e.g. Mobile and Wi-Fi sharing



- **Performing a CBA of sharing solutions** to allow **mobile and Wi-Fi to share in the same band** is a significant innovation and has not to our knowledge been attempted before
- However, the actual methodology follows core regulatory impact assessment principles:

Clear counterfactual

All relevant costs and benefits

Opportunity costs

Dealing with uncertainty

Wider social impacts if relevant

Avoid double counting

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Scenarios to be modelled

- Mobile and Wi-Fi in the upper 6 GHz band
  1. Only Wi-Fi is allowed into the upper 6 GHz band;
  2. Only IMT is allowed into the upper 6 GHz band.
  3. Both IMT and Wi-Fi with mitigation by Wi-Fi (Wi-Fi vacates)
  4. Both IMT and Wi-Fi with mitigation by IMT (IMT Med power).
- Independently operated private networks in the upper n77 band (3.8-4.2 GHz)
  1. Current separation distances, assuming medium power, (from the Ofcom interference prediction model).
  2. Lower separation distances: medium power, no additional mitigation (informed by more accurate measurements from field trials, and manually operated database);
  3. Lower separation distances: low power, no additional mitigation;

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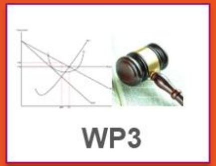
Expected outputs from the economic analysis



- We will estimate the total net present value of the sharing solution benefits to end-users and savings to operators minus the costs of implementing and running the sharing solution and any additional network deployment. This will be calculated as the incremental net benefit compared to the counterfactual (e.g. no sharing).
- We will present this result as a range of values to reflect the key sensitivities e.g. alternative strategies to mitigate interference in a shared situation could include geographical based sharing, medium vs low power operation, dynamic power adjustment through a shared access system.
- We will also try to assess the impact of variations in demand, though quantifying this is difficult due to the many uncertainties. However, we will assess whether we can credibly map demand uncertainties onto the market through end-user willingness to pay. E.g. if data demand grows more than expected, overall mobile WTP may increase and vice versa.

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