

JOINT OPERATORS TECHNICAL SPECIFICATION OF THE NEUTRAL HOST IN-BUILDING SMALL CELL SOLUTION

ANNEX 2 RADIO REQUIREMENTS

SCOPE

This Annex defines the Radio Requirements specification for the JOTS Neutral Host In-Building (NHIB) solution capable of supporting cellular services for multiple Mobile Network Operators.

This annex sets out the turn-key roles and responsibilities of the *Neutral Host Provider* for the design, installation, commission, acceptance, optimisation and maintenance of the small cell solution within the **Retailer Domain**.

PURPOSE

This specification will be used by *Operators*, *Neutral Hosts* and *Retailers* to implement instances of the Neutral Host In-Building solution. To assist in that task the overall specification is divided into a set of annexes, each covering a key aspect of the implementation:

- Annex 1 – Architecture
- Annex 2 – Radio Requirements (**This document**)
- Annex 3 – Testing and Acceptance
- Annex 4 – Operational Processes
- Annex 5 – Fulfilment

Each annex is separately version controlled. Collectively the latest versions of all the annexes define the JOTS Neutral Host In-Building specification.



JOTS 
(NEUTRAL HOST IN-BUILDING)

ANNEX 2
RADIO REQUIREMENTS

ALL RIGHTS RESERVED

This is an unpublished work. No part of this document may be copied, photocopied, reproduced, translated, or reduced to any electronic or machine-readable form without the prior permission of the JOTS NHIB forum.

DOCUMENT INFORMATION

Document Name:	JOTS NHIB Specification Annex 2 – Radio Requirements
Brief Description:	JOTS NHIB Specification
Document Author:	Kin W Wan (BT/EE)
Owner While Current:	Kin W Wan
Owner's Email Address:	kin.wan@bt.com
Issue Date:	13 th November 2023
Document contributor	David Morris (Virgin Media O2)
Document contributor	
Document contributor	
Document contributor	

ACKNOWLEDGEMENT

This document is created with inputs and contributions from the current UK mobile network operators Virgin Media O2, Vodafone, BT/EE and Three.

TABLE OF CONTENTS

1	INTRODUCTION	8
2	TECHNICAL SPECIFICATION OF THE NEUTRAL HOST IN-BUILDING SMALL CELL SOLUTION	9
2.1	GENERAL	9
2.2	DESIGN REQUIREMENT ASSUMPTIONS	10
2.3	NEUTRAL HOST IN-BUILDING SOLUTION	11
2.4	COVERAGE	11
2.5	COVERAGE OVERLAPPING BETWEEN SMALL CELLS	13
2.6	OVERLAPPING COVERAGE BETWEEN SMALL CELLS AND OUTDOOR CELLS	14
2.7	CONTROLLED LEAKAGE AND HANDOVER.....	14
2.8	OVERLOAD AND INTERMODULATION	14
2.9	CO-SITING	15
2.10	F-INTERFACE	15
2.11	HEALTH AND SAFETY	16
2.12	PERFORMANCE CHARACTERISTICS OF SMALL CELL.....	17
3	SERVICE LEVEL AGREEMENT	18
4	NEUTRAL HOST IN-BUILDING SOLUTION TESTING	19
4.1	TEST EQUIPMENT	19
4.2	COMMISSIONING AND SYSTEM ACCEPTANCE TEST	19
4.2.1	Minimum Coupling Loss.....	19
4.2.2	Coverage	20
4.2.1	Coverage Overlap Between Small Cells	21
4.2.1	Coverage Overlap between Neutral Host In-Building Cells and Outdoor Cells.....	21
4.2.1	Controlled Leakage and Handover.....	21
4.2.1	RF Exposure.....	22
4.2.1	Supervisory and Monitoring	22
4.3	LIVE COVERAGE VALIDATION.....	22
	APPENDIX A: LICENCED SPECTRUM OF THE UK CELLULAR OPERATORS	23
	APPENDIX B: SURVEY RESULT LEGENDS.....	24
	APPENDIX C: GUIDELINES ON THE GENERATION OF SURVEY ROUTES.....	25
	APPENDIX D: CONCESSION TEMPLATE.....	26

PARAGRAPH MARKINGS

Throughout this specification, the following paragraph markings are used:

- M** A mandatory and critical requirement that must be met by the solution. Details shall be provided stating how mandatory requirements have been met within any proposed solution.
- R** A requirement of the specification. These are to be considered mandatory to the extent that non-compliance will require the *Neutral Host* to provide to the *Operator* (or visa-versa) specific justification as to why they are not compliant to the requirement.
- I** Informative statement, providing either points of clarification or a statement relating to implementation good practice.

GLOSSARY AND ABBREVIATIONS

3GPP	3 rd Generation Partnership Program
Aggregation Function	A device capable of aggregating S1 connections
b -interface	Interface between the Neutral Host Domain and the Operator Domain
BTS	Base Station (e.g. picocell, eRAN cell, femtocell)
Controller	Aggregation unit (services node) for controlling and aggregating multiple BTS
CPE	Customer Premises Equipment (switches and routers)
CSFB	Circuit Switched Fall-Back
dB	Decibel (logarithmic scale factor)
dBi	Logarithmic unit of antenna gain relative to isotropic radiation
dBm	RF power (in dB) relative to 1 milliwatt
EGCI	E-UTRAN Cell Global Identifier
EMF	Electromagnetic Field
eNodeB	4G E-UTRAN base station
eRAN	Enterprise Radio Access Network
ETSI	European Telecommunications Standards Institute
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
f -interface	Interface between the Retailer Domain and Neutral Host Domain
FR1	Frequency Range 1 (410MHz – 6GHz (7.125GHz (to be confirmed)))
gNodeB	5G NR base station
GSM	Global System for Mobile Communication
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IET	Institution of Engineering and Technology
LAN	Local Area Network
LOI	Location of Interest
LTE	Long Term Evolution (Radio Access Technology) (a.k.a. 4G)
LTE-R	LTE for rail applications
LTE-U	LTE which utilizes unlicensed spectrum
MCL	Minimal Coupling Loss
Mgmt	Management
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity (4G core element)
MNO	Mobile Network Operator
MT	Mobile Terminating
MuLTFire	LTE which utilizes unlicensed spectrum (Qualcomm)
NAT	Network Address Translation (IP layer 3)
NB-IoT	Narrowband-Internet of Things
NCGI	NR Cell Global Identifier
NHIB	Neutral Host In-Building
NHP	Neutral Host Provider (entity who installs radio solution into venue)
NMAS	National Measurement Accreditation Service
NR	New Radio (5G)
NTE	Network Termination Equipment (backhaul provider)
Ofcom	Office of Communications (UK Government regulatory authority)
OFDM	Orthogonal Frequency Division Multiplexing
pBTS	Picocell BTS

PKI	Public Key Infrastructure
pRRU	Picocell Remote Radio Unit
RFID	Radio Frequency Identification
RS	Reference Signal
RSRP	Reference Signal Received Power
SAR	Specific Absorption Rate
SC	Small Cell (low power in-building radio node)
SGW	Serving Gateway (4G core element)
SSO	Single Sign-On
TACACS+	Terminal Access Controller Access Control System Plus
Tier 1b SecGW	b -interface security gateway (within Neutral Host Domain)
Tier 1f SecGW	f -interface security gateway (within Neutral Host Domain)
Tier 2 SecGW	b -interface security gateway (within Operator Domain)
UMTS	Universal Mobile Telecommunications System
WLAN	Wireless Local Area Network (a.k.a. Wi-Fi)

1 INTRODUCTION

The Neutral Host In-Building small cell (NHIB SC) deployment is separated into three domains: the **Retailer Domain**¹, the **Neutral Host Domain** and the **Operator Domain**, with the key areas as shown in *Figure 1-1*. This annex mainly focuses on the radio access design requirements of the NHIB SC solution capable of supporting 4G and 5G mobile cellular services² as a minimum for multiple Mobile Network Operators in the **Retailer Domain**, and the acceptance tests carried out by the *Neutral Host Provider* (NHP) for the Mobile Network Operators (MNOs). The Testing and Acceptance requirements applied to the **Neutral Host Domain** are covered in Annex 3.

It is expected that the NHP is responsible for the turn-key delivery of the NHIB SC solution within the **Retailer Domain**, from the initial concept, through implementation surveys, design, to final installation, commissioning and maintenance.

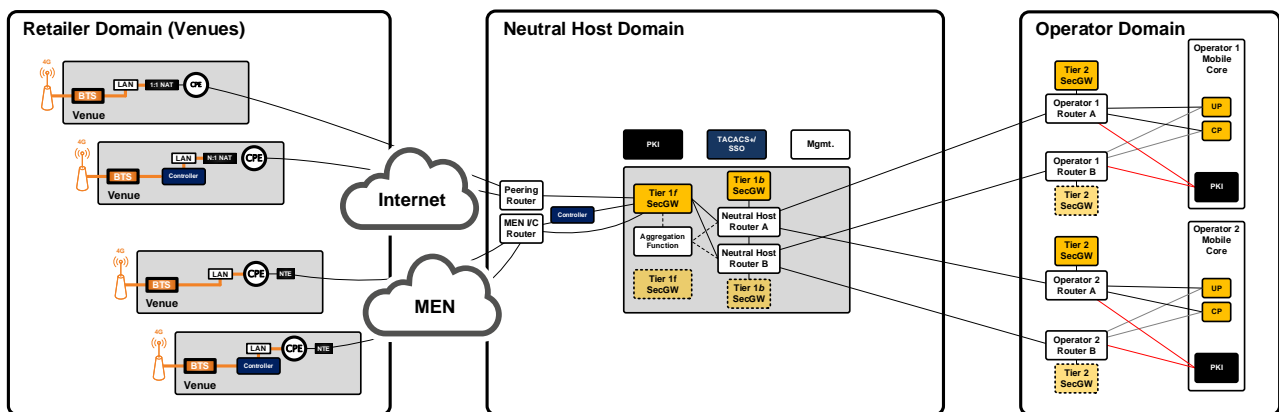


Figure 1-1 - Domain Overview

¹ For the avoidance of doubt, a *Retailer* within the **Retailer Domain**, in this context, is not a ‘shop’, but an entity whose commercial model is built around providing in-building coverage solutions to venues.

² The mobile cellular services are referred to the general public services of Personal Communication Networks (PCNs). For the provision of specific services beyond the PCN general public services for a specific MNO, the NHP should liaise with that MNO directly in terms of specific requirements.

2 TECHNICAL SPECIFICATION OF THE NEUTRAL HOST IN-BUILDING SMALL CELL SOLUTION

2.1 General

1. R The NHP shall engage with the MNOs during each stage of a project.
2. M The Small Cell (SC) solution shall be designed for delivering LTE coverage and services as a minimum.
3. M An appropriate capacity dimension shall be provided according to the expected traffic and footfall, which is applied to both the radio resources in the **Retailer Domain** and the *f*-interface between the **Retailer Domain** and the **Neutral Host Domain**.
4. M The design and the performance of the SC solution shall not be compromised by the presence of other technologies and devices.
5. M Where a venue already has a dedicated in-building cellular mobile coverage system(s) installed, the NHP must carry out an assessment of the impact of deploying their own NHIB SC solution at the same venue.
6. R Where multiple coverage zones are provided by the NHIB SC solution, the zone definition has to be clearly defined.
7. M The SC solution shall be capable for 2x2 MIMO as a minimum.
8. M The NHIB SC solution shall meet the 3GPP and ETSI Standards, and also conform to all the current regulations, rules and the operation conditions imposed on MNOs by the UK Government according to the frequency spectrum acquired by individual MNOs.
9. M The NHIB SC solution shall be capable of covering the 1800 MHz, 2100 MHz, 2600 MHz and 3400-3800 MHz bands to meet all the MNOs spectrum usage requirements. Where possible, additional frequency bands should be considered. (See Appendix A regarding the licensed spectrum of the UK mobile network operators).
10. R It is recommended that the *Neutral Host* checks with each hosted *Operator* that their solution supports BTS feature sets and capabilities required by each *Operator*. Additionally, the *Neutral Host* should check with each hosted *Operator* as to whether the specific venue needs special consideration in terms of BTS feature sets and capabilities.

- 11. M The NHP and/or Neutral Host shall ensure that the tenant, landlord and visitors to the building are made aware that the in-building radio solution is only 4G/5G capable. Thus, visitors to that building with devices which are either not VoLTE capable or not VoLTE enabled will not be able to make Circuit Switched Fall-Back (CSFB) emergency calls via the inbuilding system. Instead they will rely on the preexisting *Operator* coverage provided by external macrocells or fixed line services to make emergency calls.
- 12. I The NHIB SC unit can be equipped with internal integrated antennas or external antenna interfaces for specifically delivering and controlling the mobile coverage and services in a specific area.
- 13. R The NHIB SC solution shall be used in indoor and confined space environments such as, but not limited to, office, hotel, conference and exhibition centre etc.

2.2 Design Requirement Assumptions

- 14. R The propagation model and performance requirements as specified in TS36.104³ Case 1 for a mobile terminal travelling at a speed up to 3 km/hr.
- 15. R The NHP can assume:
 - Mobile terminal maximum transmit power of 23 dBm;
 - Mobile terminal minimum transmit power of -40 dBm;
 - the dedicated solution should provide at least a dominant coverage of 6 dB over 95% of the coverage target area against the coverage provided by the external outdoor cell sites of any adjacent cellular networks;
 - Reference Signal (RS) power is equal to the average sub-carrier power of LTE

$$P_{FL} = 10 \times \text{Log}_{10}(N_{sc}),$$

Where P_{FL} is referred to the full load channel carrier power assigned to a given MNO and N_{sc} is the number of LTE sub-carriers in a given LTE channel bandwidth;

- NR channel carrier power is evenly assigned to all sub-carriers including Secondary Synchronization Signal Energy Per Resource Element (SSS EPRE) of Synchronization Signal Block (SSB) within the transmission channel. The SSS EPRE is related to the sub-carrier spacing and the number of resource blocks within a given 5G NR channel bandwidth as noted below.

Transmission bandwidth configuration N_{RB} for FR1													
SCS [kHz]	5MHz	10MHz	15MHz	20 MHz	25 MHz	30MHz	40 MHz	50 MHz	60 MHz	70MHz	80 MHz	90MHz	100
15	25	52	79	106	133	[160]	216	270	N.A	N.A	N.A	N.A	N.A
30	11	24	38	51	65	[78]	106	133	162	[189]	217	[245]	273
60	N.A	11	18	24	31	[38]	51	65	79	[93]	107	[121]	135

- 16. R For the purpose of overlapping coverage design, including the portals of the venue to and from the external MNO macro networks, the maximum and minimum handover time for mobile terminal travelling speed >3km/hr and <=3km/hr is 10 and 4 seconds respectively. S1 and NG only handovers are considered for LTE and NR respectively.

³ TS 36.104 Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception.

17. R For the purpose of the design, a body loss of 5 dB can be used in the link budget assumption.

2.3 Neutral Host In-Building Solution

18. R The NHIB SC solution can take the form of:

- a single small cell unit for a single MNO (1 x MNO per eNodeB/gNodeB);
- a single small cell unit for multiple MNOs (n x MNOs per eNodeB/gNodeB);
- co-sited multiple small cell units for a single MNO or multiple MNOs;
- distributed multiple small cell units as a single-cell network with a unique E-UTRAN/NG-RAN Cell Global Identifier (ECGI)/(NCGI) or multiple-cell networks with multiple ECGIs/NCGIs for a single MNO or multiple MNOs;
- serving a single frequency band or multiple frequency bands.

19. I The small cell unit refers to a self-contained pico base station (pBTS) or a pico remote radio unit (pRRU) connected to a separate baseband unit.

2.4 Coverage

20. R The coverage requirements refer to both downlink and uplink within the coverage target areas of the Location of Interest (LOI) and with mobile terminal at the height of 0.5 m to 2 m above the local ground.

21. R Unless specified in a separate agreement between the NHP and the individual MNO, the NHP shall ensure that the NHIB SC solution delivers coverage to the standard defined in Table 2 below which is referred to the initial targets and has to be validated against the dominance requirements defined in section 2.2.

LTE and NR (hand held MT – in-building)			
Type of zone	A: High data rate service	B: Medium data rate service	C: Portal area ONLY
95% downlink reference coverage (reference signal received power, RSRP for LTE; synchronization signal reference signal received power SS-RSRP for NR) (*)	>-95 dBm	>-105 dBm	>-110 dBm
95% uplink loss	<110 dB	<120 dB	<125 dB
Typical area	Zone A: low mobility and high density mobile. Zone B: medium mobility and low/medium density mobile. Zone C: portal area ONLY.		
Example (not exhaustive list. Each venue MUST be analysed and assessed on a case by case basis.)	Zone A: <ul style="list-style-type: none"> - Airport: lounge, restaurant/bar, shopping area, departure gate; - Shopping Centre: food court, restaurant/bar, seating area; - Sport venue: seating area, hospitality/concourse area; - Hotel/conference centre/exhibition centre: conference/meeting area, public break-out area, restaurant/bar; - Senior management offices. Zone B: <ul style="list-style-type: none"> - Airport: arrival gate, transit area; - Shopping Centre: back of the shop where public can access - Sport venue: public transit area other than the concourse area mentioned in zone A; - Hotel: any other areas subject to a separate agreement between MNO and NHP; - Residential multi-dwelling units; - General offices. Zone C: <ul style="list-style-type: none"> - any transition from the areas served by the dedicated indoor system to the adjacent cellular network which can be another indoor cell or the outdoor cellular network. Note: <ul style="list-style-type: none"> - corporate coverage is likely to be designed as the requirements for Zone A but it will be subject to a separate agreement between an individual MNO and NHP. 		

Table 2-1: Coverage Specification.

(*) RSRP for each cell is the linear average over the power contributions of the Resource Elements that carry cell-specific Reference Signals within the considered measurement

frequency bandwidth. It can therefore only be referred to and measured in the OFDM symbols carrying reference symbols. SS-RSRP is the linear average of the secondary Synchronization Signal Reference Signal Received Power. The secondary synchronization signals on the Resource Elements are cell-specific to each NR cell

- 22. R The NHP shall propose and define the zone types in each design as a reference for MNOs.
- 23. R The uplink link loss defined in Table 2-1 is the end-to-end loss between the mobile terminal and the antenna interface connection to the receiver of the small cell unit. Where the small cell unit is with an internal integrated antenna, the gain of the antenna shall be taken into account with the assumption of 0 dB cable loss between the antenna and the small cell receiver.
- 24. R The NHP must make allowances for the floor variations, fading, clutter loss and environment in the design in order to ensure the required percentage of the LOI is covered.
- 25. R Busy traffic zones such as Zone A do not necessarily mean that more small cell units will be required. The placement of the small cell units and the sectorisation of the small cell solution shall take into consideration that the demand of higher data rate and capacity are most likely at places where the mobile terminals can be stationary or quasi-stationary such as lounges, restaurants and cafés, etc.

2.5 Coverage Overlapping Between Small Cells

- 26. R Where multiple small cell units as a single cell or as multiple cells are required for a given MNO network, the NHP shall design that the coverage delivered by the small cells has adequate overlap without discontinuity of service in the coverage area
- 27. R Where multiple cells are proposed, the cell boundary shall have adequate coverage overlap enabling a mobile terminal to complete a handover within the handover time defined above.
- 28. R The coverage overlap of multiple cells shall avoid the high traffic area in order to minimise the handover between them.
- 29. R The design should provide an indication of the number of users per small cell zone.
- 30. R NHP shall state the capacity of the small cell unit per band.
- 31. R The overlapping coverage areas provided by any two adjacent indoor cell networks shall be less than 15% of the coverage area of two networks with reference to the equal RSRP coverage boundary +/- 3 dB window.

2.6 Overlapping Coverage Between Small Cells and Outdoor Cells

32. R The NHP shall design the solution such that the portal shall be adequately covered without breaching the controlled leakage requirements defined in section 2.7. This shall ensure a proper handover in both directions between the indoor cell(s) and the external cells which are defined as the cell(s) not under the responsibility of the NHP.
33. R The handover between the outdoor cells and the indoor cells may be of inter-frequency nature, i.e. hard handover which will take longer to complete. Therefore, the overlapping coverage distance between the outdoor cell and the indoor cells at the portals shall ensure continuous voice call for a mobile terminal at the speed as defined in section 2.2
34. R For reason of avoiding uncertainty and conflict of responsibility, it is a preference, where possible, that all handovers occur inside the LOI.

2.7 Controlled Leakage and Handover

35. R The distance of the controlled leakage from the LOI is with reference to a mobile terminal at the speed as defined in section 2.2 and also takes the minimum handover time into account.
36. R The maximum distance of the signal overspill from any portals of the LOI shall be less than 3 m with the RSRP/SS-RSRP level <-118 dBm.
37. R With the exception of the portals of the LOI, the maximum distance of the signal overspill outside the boundary of the coverage target area shall be less 3 m with the RSRP/SS-RSRP level <-121 dBm.

2.8 Overload and Intermodulation

38. R The selection and the placement of the small cell units shall meet the minimum coupling loss (MCL) requirement of 45 dB, and not cause overloading, blocking and de-sensitisation to the mobile terminal in the downlink direction, and the small cell in the uplink direction due to the presence of a mobile terminal transmitting at full power within the coverage range of the radiating element, especially in close proximity to the radiating element concerned.
39. R MCL is referred to the location at where the minimum path loss between the mobile terminal and the small cell unit, and the mobile terminal will receive the maximum downlink signal and the small cell will receive the maximum uplink signal.

40. R The NHP shall carry out an assessment for each design, state the MCL which will be achieved and ensure the downlink and uplink overload, blocking and de-sensitisation will not occur. The maximum downlink signals at 4G and 5G mobile terminals shall be less than -25 dBm per cellular channel, and the maximum uplink signal level per cellular channel at any small cells shall be less than -41 dBm or -33 dBm according to the small cell (base station) classification⁴ of local area or home respectively. Consideration of the small cell locations, antenna types (if external antennas are used) and/or the overall system design may be necessary to achieve both coverage and overload requirements.
41. R The NHP shall endeavor to position the small cell such that a far mobile terminal at the edge of the coverage area will not be affected by a near and uncoordinated mobile terminal at the MCL position of the same small cell, transmitting 30 dBm, 21 dBm, 23 dBm and 23 dBm at the GSM, UMTS, LTE and NR frequency band respectively. The uncoordinated mobile terminal is due to the MNO who does not subscribe to the NHIB SC solution or/and whose mobile terminal makes a voice call on a legacy GSM or UMTS network (utilizing CSFB).
42. R Where the same or different small cell units are shared or co-located, and they operate at the same or different frequency bands, any uplink and downlink intermodulation products and spuri generated under full load downlink conditions shall still comply with the appropriate specifications recommended by the 3GPP Standards, and the network performance shall not be degraded.

2.9 Co-Siting

43. R The NHP shall ensure that the system is designed to prevent any significant mutual interference between 4G and 5G channels of the MNOs and other telecommunication installations in the premises at the time of design and installation. This includes, but is not limited to, the presence of wireless local access network (WLAN), ultra wide band (UWB) device, RFID, LTE-U, MuLTEFire and LTE-R.
44. R The effective degradation to the uplink and downlink and DL receive sensitivity due to the effect of co-siting shall not be more than 0.1 dB.

2.10 *f*-interface

45. R *f*-interface connectivity responsibility lies with the *Retailer* or *Neutral Host Provider* within the **Retailer Domain**.

⁴ With reference to 3GPP TS 36.104, Local Area Base Stations are characterised by requirements derived from Pico Cell scenarios. Home Base Stations are characterised by requirements derived from Femto Cell scenarios.

2.11 Health and Safety

46. R In terms of the NHIB SC solution related to human exposure to electromagnetic fields (EMF), appropriate exposure limits defined by ICNIRP standard according to the implementation conditions shall be used.
47. R The NHP shall take the full responsibility for the risk assessment where the public or occupational EMF limit is applied to each radiating element. The EMF exposure limit for the general public shall be used in any public accessible locations.
48. M Maximum radiated power from any single small cell unit shall be touch safe and shall not expose anyone to an EMF level which exceed the current guidelines in the ICNIRP standard. The Specific Absorption Rate (SAR) threshold, i.e. 2 W/kg within 10 g volume, is applied.
49. M The NHP shall issue an ICNIRP compliance statement for every design.
50. M The NHIB SC solution shall be designed and built to meet all the relevant building and construction products regulations⁵ in particular in areas concerning health and safety.
51. M All the electrical installations shall follow the IET wiring guidelines⁶.
52. M The NHP is wholly responsible for the health and safety of the the NHIB SC solution.

⁵ The Construction (Design and Management) Regulations 2015.

⁶ IET Wiring Regulations, BS 7671:2018, 18th Edition.

2.12 Performance Characteristics of Small Cell

53. M The small cell unit must be type approved to the appropriate 3GPP recommendation.
54. M As specifically required by Ofcom, any out-of-band emission spuri:
 - radiated by any radiating elements of the NHIB SC solution, between 2500 MHz and 2615 MHz and also between 2700 MHz and 3100 MHz, shall be <-45 dBm/MHz (EIRP);
 - below 3390 MHz and also between 3410 MHz and 3800 MHz, but outside the permitted frequency blocks granted to MNOs, shall be <-52 dBm/MHz (EIRP);
 - between 3390 MHz and 3410 MHz and also between 3800 and 3840 MHz, shall be <-7 dBm/MHz (EIRP); and
 - above 3840 MHz, shall be <-21 dBm/MHz (EIRP).
55. M The **Neutral Host/Retailer Domains** will be responsible for selecting an appropriate transport technology to meet the bit rate, latency, jitter and packet loss performance requirements of the **f**-interface component of the radio solution.
56. R The frequency stability of the small cell unit shall conform to 3GPP recommendation.

3 SERVICE LEVEL AGREEMENT

57. R It is expected that the NHP will be responsible for the maintenance of all the equipment used in the NHIB SC solution and the equipment room and its accessories.
58. R The maintenance regime and a service level agreement shall be agreed with the individual participating MNO by the *Neutral Host*.
59. R The NHP shall make arrangement with the site owner permitting the MNO, on request, unlimited access for checking the functioning of the NHIB SC solution for network quality assurance purposes.
60. R Contractual details shall be covered under separate commercial agreements.

4 NEUTRAL HOST IN-BUILDING SOLUTION TESTING

61. R Commissioning and system acceptance tests for verifying the design and installation of the system shall be conducted by the NHP. The test results shall be provided on request to the participating MNOs who may individually opt to be included in the site commissioning and system acceptance process.

4.1 Test Equipment

62. R All the test equipment must be fully calibrated by nationally recognised establishment such as National Measurement Accreditation Service (NMAS).
63. R All the test equipment used shall have a next calibration date that is at least one month away.
64. R The test report shall have a chapter listing all the equipment used in the tests with the specific details on the type, model, calibration date and the next calibration.
65. R Calibration certificate shall be made available for inspection if required.
66. R All test equipment used shall be fit for purpose i.e. a radio scanner is sensitive enough to RSRP level well below -121 dBm and/or a test handset meeting 3GPP Standards.

4.2 Commissioning and System Acceptance Test

67. R The commissioning and system acceptance tests shall be carried out by the NHP after the installation of the NHIB SC solution. The main objectives are to verify the performance of the NHIB SC solution under a controlled environmental condition in a test mode configuration that no commercial users are on the solution prior to the commercial launch.
68. R The test results and calculations of each test shall be included in the report which shall form part of the handover document. Where a high gain antenna, instead of a 0 dBi antenna, is used in a scanner for the downlink coverage measurements, an appropriate offset of the measured results including the effects of high gain downlink coverage antenna and the associated cable loss between the antenna and the test receiver/scanner shall be taken into account.

4.2.1 Minimum Coupling Loss

69. R The maximum downlink RSRP coverage level at 1.5 m above the local ground level for each small cell unit shall be measured to confirm the maximum loading threshold.

70. R With the assumption of reciprocal air interface between the downlink and uplink, based upon the maximum downlink RSRP coverage results, the maximum uplink signal to the small cell unit at the MCL local shall be assessed accordingly.
71. R The results shall be presented in a structured table for easy tracking and review.

4.2.2 Coverage

72. R For reasons of convenience, the measurement can be conducted over the downlink direction for each band. However, with the measurement results of the downlink coverage and the uplink performance, analysis shall be provided to confirm the coverage level, coverage quality and system link loss meeting the requirements given in this specification
73. R Where the coverage or link loss fails to meet the requirements of this document, the NHP shall carry out an investigation to identify the cause(s) of the shortfall. Where the shortfall is due to the design, the NHP shall seek for the resolution. Where the rectification is not possible, a concession has to be submitted to the MNO for an approval. Where the shortfall of the system is due to the installation, no concession will be accepted, and the NHP shall get the system fixed (see the concession template form in Appendix D).
74. R The statistics of the results shall be provided to demonstrate that the requirements of the coverage and the link loss are met.
75. R For the confirmation of the downlink coverage met, 95% of the measured RSRP and SS-RSRP downlink signals, $R_{x95\%}$ (the level at 95% of the cumulative distribution function of the measured downlink coverage signals), in the coverage target area shall be greater than or equal to the requirements given in section 2.4.
76. R Without taking the radio propagation difference at the downlink and associated uplink bands into account, for the confirmation of the uplink link loss met as the requirements given in section 2.4, based upon the downlink coverage measurement results, the uplink link loss, $L_{UL95\%}$, at 95% coverage of the target area shall be calculated with:
- $L_{UL95\%} = T_{xDL} - R_{x95\%}$
- Where T_{xDL} represents the transmit power of LTE Reference Symbol or NR secondary Synchronization Signal Reference Symbol associated with the corresponding LTE RSRP or NR SS-RSRP at the receive side, as noted in section 2.2.
77. R The measured coverage results are plotted on the floor plan layouts with continuous snail trail of samples based upon the travelling speed of the test equipment ≤ 3 km/hr and the measurement

sampling time interval ≤ 1 second. The threshold levels in dBm and dB used in the coverage and link loss plots respectively shall be:

- Equivalent LTE RSRP and NR SS-RSRP coverage plot: ≥ -65 , $(-65, -75]$, $(-75, -85)$, $(-85, -95]$, $(-95, -105]$, $(-105, -110]$, $(-110, -113]$, $(-113, -116]$, $(-116, -118]$, $(-118, -121]$ and < -121

where $(x, y]$ is referred to any values within the range from x to y and including y but excludes x . In addition, a summary table summarising the corresponding downlink coverage levels and the corresponding uplink link loss levels of 5%, 50% and 95% percentile for each coverage target zone is required. Legend formatting is prescribed in Appendix B.

78. R The NHP shall propose the survey routes for each of the LOI and follow the guidelines described in Appendix C where possible.
79. R Where LOI has a very large footprint, the coverage area shall be divided into multiple survey zones and the coverage statistics of each zone shall be produced. Each of the zones shall meet the agreed coverage requirement. The NHP shall propose the zones for MNO agreement.

4.2.1 Coverage Overlap Between Small Cells

80. R This test is not required for every small cell unit configured as the same cell because it is the NHP's responsibility to ensure contiguous coverage within the LOI, however this test is required at the expected coverage boundaries where the small cell units are divided for serving different cells for capacity reason. Within the coverage overlap area, the signal level shall not be less than that derived from the permitted link loss by 3 dB.
81. R The measured signal level difference of two adjacent cells in the coverage target areas shall be plotted on the layout map. The test results shall be analysed to confirm the coverage overlapping requirement met, and the coverage overlapping region(s) are adequate for call handover according to the handover time required and the speed of the mobile terminal defined.

4.2.1 Coverage Overlap between Neutral Host In-Building Cells and Outdoor Cells

82. R This test shall be carried out at each of the portals of the LOI.
83. R With reference to the equal power boundary of the indoor and outdoor cell ± 3 dB, the downlink coverage overlapping distance between the indoor and outdoor cells shall be measured from the portals to the external of the LOI.

4.2.1 Controlled Leakage and Handover

84. R To assess the impact of the interference to the existing cellular network due to the NHIB SC solution, the NHP shall carry out measurements of the RF leakage immediately and at a distance of 3 m, 6 m and 12 m (wherever possible) around the building external wall of the LOI. Where the leakage

measurement cannot be taken around the building external wall of the LOI, the distances from the LOI and the corresponding signal levels shall be noted and reported.

4.2.1 RF Exposure

- 85. R The NHP shall confirm that the NHIB SC solution installed is compliant to the ICNIRP recommendation according to the SAR thresholds.
- 86. R Where the external antennas are used for those small cells, the NHP shall calculate the composite RF power to be delivered at the connector of each radiating element under full load condition.
- 87. R The analysis results shall be presented in a table format confirming the compliance of each radiating element.

4.2.1 Supervisory and Monitoring

- 88. R The NHP shall carry out a test on the supervisory system by simulating all the appropriate faulty conditions. An alarm and the corresponding indicator shall turn on and a summary alarm of the affected venue shall be created.
- 89. R The alarm shall remain on until a remedy action has been specifically taken.
- 90. R Test conditions shall also be created simulating faults for the triggering of a summary alarm in the MNO's network management centre. This test will require the co-operation of the participating MNO.

4.3 Live Coverage Validation

- 91. R MNO reserves the right to carry out the mobile coverage validation. The NHP shall provide logistical support to the MNO and assist the site access for the MNO to carry out the post-integration coverage and service tests.

Appendix A: LICENCED SPECTRUM OF THE UK CELLULAR OPERATORS

Operator	Designation band	Technology	Mobile transmit (MHz)		Base transmit (MHz)	
			UPLINK		DOWNLINK	
			Lower limit	Upper limit	Lower limit	Upper limit
BT/EE	700 MHz FDD	NR 5G	723.0	733.0	778.0	788.0
	800 MHz FDD	LTE	837.0	842.0	796.0	801.0
	1800 MHz FDD	GSM, LTE	1736.7	1781.7	1831.7	1876.7
	2100 MHz FDD	UMTS, LTE	1959.7	1979.7	2149.7	2169.7
	2100 MHz TDD	UMTS, LTE	1899.9	1909.9	1899.9	1909.9
	2600 MHz FDD	LTE	2520.0	2570.0	2640.0	2690.0
	3500 MHz TDD	5G NR	3540.0	3580.0	3540.0	3580.0
	3700 MHz TDD	5G NR	3680.0	3720.0	3680.0	3720.0
Virgin Media O2	700 MHz FDD	5G NR	703.0	713.0	758.0	768.0
	900 MHz FDD	GSM, UMTS, LTE	885.1	890.1	930.1	935.1
		GSM, UMTS, LTE	902.5	914.9	947.5	959.9
	800 MHz FDD	LTE	852.0	862.0	811.0	821.0
	1800 MHz FDD	GSM, LTE	1710.1	1715.9	1805.1	1810.9
	2100 MHz FDD	UMTS, LTE	1934.9	1944.9	2124.9	2134.9
	2100 MHz TDD	UMTS, LTE	1909.9	1914.9	1909.9	1914.9
	2300 MHz TDD	LTE	2350.0	2390.0	2350.0	2390.0
	2600 MHz TDD	LTE	2595.0	2620.0	2595.0	2620.0
	3500 MHz TDD	5G NR	3500.0	3540.0	3500.0	3540.0
3700 MHz TDD	5G NR	3760.0	3800.0	3760.0	3800.0	
Three UK	700 MHz FDD	5G NR	713.0	723.0	768.0	778.0
	800 MHz FDD	LTE	832.0	837.0	791.0	796.0
	1800 MHz FDD	GSM, LTE	1721.7	1736.7	1816.7	1831.7
	2100 MHz FDD	UMTS, LTE	1920.0	1934.9	2110.3	2124.9
	2100 MHz TDD	UMTS, LTE	1914.9	1920.0	1914.9	1920.0
	1400 MHz SDL	LTE			1472.0	1492.0
	3400 MHz TDD	5G NR	3460.0	3500.0	3460.0	3500.0
	3600 MHz TDD	5G NR	3580.0	3680.0	3580.0	3680.0
4000 MHz TDD	5G NR	3925.0	4009.0	3925.0	4009.0	
Vodafone	800 MHz FDD	LTE	842.0	852.0	801.0	811.0
	900 MHz FDD	GSM, UMTS, LTE	880.1	885.1	925.1	930.1
		GSM, UMTS, LTE	890.1	902.5	935.1	947.5
	1800 MHz FDD	GSM, LTE	1715.9	1721.7	1810.9	1816.7
	2100 MHz FDD	UMTE, LTE	1944.9	1959.7	2134.9	2149.7
	2600 MHz FDD	LTE	2500.0	2520.0	2620.0	2640.0
	2600 MHz TDD	LTE	2570.0	2595.0	2570.0	2595.0
	1400 MHz SDL	LTE			1452.0	1472.0
	3400 MHz TDD	5G NR	3410.0	3460.0	3410.0	3460.0
3700 MHz TDD	5G NR	3720.0	3760.0	3720.0	3760.0	

Appendix B: SURVEY RESULT LEGENDS

R G B	legend	LTE RSRP/NR SS-RSRP [dBm]
225 255 255		≥-65
176 255 255		(-65,-75]
0 255 255		(-75,-85]
0 75 224		(-85,-95]
0 255 0		(-95,-105]
0 153 0		(-105,-110]
255 255 0		(-110,-113]
255 153 0		(-113,-116]
255 0 255		(-116,-118]
255 0 0		(-118, -121]
48 48 48		<-121

R G B	legend	Uplink link loss [dB]
176 255 255		≤60
0 255 255		(60,80]
0 75 224		(80,110]
0 255 0		(110,120]
0 153 0		(120,125]
255 255 0		(125,130]
255 153 0		(130,133]
255 0 0		(133,136]
48 48 48		>136

R G B	legend	LTE SNR/NR SS-SNR [dB]	LTE RSRQ/NR SS-RSRQ
0 255 255		>20	>-6
0 255 0		(14,20]	(-9,-6]
255 255 0		(6,14]	(-12,-9]
255 153 0		(0,6]	(-15,-12]
255 0 0		< 0	< -15

Appendix C: GUIDELINES ON THE GENERATION OF SURVEY ROUTES

Below is guidance on the generation of survey routes. The NHP shall use common sense, bearing in mind the main objective of the testing is to verify that the NHIB SC solution will deliver the required signal level to mobiles used by the general public. Where the guideline is not possible, the NHP should use common sense proposing alternatives.

- C.1 Passages ≤ 7 m wide: Passages not more than 7 m wide shall be surveyed along a route defined by the centre-line of the passage with a tolerance of ± 1 m.
- C.2 Passages >7 m wide: Passages wider than 7 m shall be surveyed along routes on both sides of the passage at a distance of 2 ± 1 m from the passage walls.
- C.3 rooms ≤ 5 m wide: Rooms with an average width of not more than 5 m shall be surveyed on routes around the internal perimeters, at a distance of 1 ± 1 m from the perimeter wall. Where this route is not accessible then the nearest public accessible route shall be taken.
- C.4 $5 \text{ m} < \text{Room width} \leq 10 \text{ m}$: Rooms with an average width of between 5 m and 10 m shall be surveyed on routes around the internal perimeters, at a distance of 1 ± 1 m from the perimeter wall and along a centre-line parallel to the longest wall of the room. Where this route is not accessible then the nearest public accessible route shall be taken.
- C.5 Room width >10 m: Rooms with an average width greater than 10 m shall be surveyed on routes around the internal perimeters, at a distance of 2 ± 1 m from the perimeter wall and along zigzag route sweeping the floor area. The pitch of the zip-zap route shall be not more than 4 m. Where this route is not accessible then the nearest public accessible route shall be taken.
- C.6 Stairs and escalators: Stairs and escalators shall be surveyed along the centre line of the stair or escalator. Where multiple stairs or escalators are located within the same passageway or bore, then the survey routes shall be along the stair or escalator located nearest to the centreline of the passageway or bore. Where stairs and escalators are contained within separate passageways or bores, they shall be treated as separate stairs and escalators.
- C.7 Port of entry (entrances and exits): Entrances and exits shall be surveyed along a centre-line route normal to the entry or exit doorway, or as near as is practically possible by the general public. The route shall be extended to at least 10 m on either side of the port of entry.
- C.8 Building perimeter: The perimeter of the building shall be surveyed along the nearest publicly accessible route. Surveying is not required if the nearest publicly accessible route is over 10 m from the building perimeter. In all the above cases, where obstacles prevent or impede public access, then the nearest publicly accessible route shall be taken to get back onto the defined survey route.
- C.9 Railway carriage: Railway carriage shall be surveyed with a walk along the centreline of the carriage and at sitting position on every five-aisle seat inside the carriage.
- C.10 Car park: Car parks shall be surveyed using a typical saloon vehicle along all designated entrance, throughway and exit routes.

Appendix D: CONCESSION TEMPLATE

Site Details			
Cell ID		Date of issue	
Site Name		Issue version	
Site Address			

Concession Approval			
NHP name	Prepared by	Name in block	Signature
	Telephone		date
	Checked by	Name in block	Signature
	Position		date
CNO	Approved by	Name in block	Signature
	Position		date

Concession Details		
Concession		
Affected Area		
Supporting Doc.	Performance statistics <input type="checkbox"/> Plots/Drawings <input type="checkbox"/>	Ref: Ref:
Remedy Proposal		
Est. Completion Date		

--- End of Document ---